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Signalised Roundabouts

Guidelines

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Contents

Figures

Tables

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1 PURPOSE

A well designed signalised roundabout offers a unique solution to a complex traffic problem; providing safe access for all road users, and providing adequate capacity to service vehicular demand. Roundabouts have long been highly regarded for their safety merits of meeting Safe Systems design principles by reducing vehicular speed through the intersection, minimising the number of conflict points within an intersection, and minimising the angle of conflict. Roundabouts can also provide comparable capacity to that of a signalised intersection. Notwithstanding this, roundabouts, and multi-lane roundabouts in particular do not cater well for pedestrians and cyclists: "Traffic signals would be preferred instead of multi-lane roundabouts in high activity areas for pedestrian and cyclist safety and accessibility" (Austroads, 2020b). On the other hand, provided key criteria are met, a signalised roundabout can retain the vehicular safety and capacity attributes of a priority-controlled roundabout, while also improving safety for vulnerable road users. In fact, a signalised roundabout can offer improved safety performance over priority-controlled roundabouts by simplifying the decisions for road users – rather than judging gaps in approaching traffic, the decision to enter a traffic stream is simplified to that of just obeying a traffic signal.

Signalised roundabouts have been recognised in recent literature (Austroads, 2017a) as providing the greatest alignment with Safe Systems objectives. They have been regularly implemented in the UK for almost 50 years, in New Zealand for 15 years, and have been implemented with some success in the East Coast of Australia. The full signalisation of the Eelup Rotary in Bunbury in 2012 (originally an unsignalised roundabout) has been an outstanding success, both from a safety and operational perspective. As the population and road use demand in Western Australia continues to grow, the signalisation of existing roundabouts and the construction of new signalised roundabouts will help WA to meet its goals of Towards Zero road fatalities by 2050.

This document provides guidance for assessing whether an existing priority-controlled or metered roundabout is suitable for conversion to a signalised roundabout, or if a new intersection is a suitable candidate for installation of a signalised roundabout. It documents the process to be followed for assessment of a candidate location, and the geometric, operational and traffic analysis considerations that should be addressed in the development of a design solution that targets the safe and efficient access for all road users.

Signalised roundabouts might not be an appropriate solution where the right turn demand on one of more approach legs is very high, on roundabouts with a small central island diameter where internal storage is restricted, and at locations with a high 'Place' value on the Movement and Place network. This document also outlines the geometric considerations and traffic characteristics where signalised roundabouts may not be an appropriate form of intersection control, and the potential disbenefits associated with signalised roundabouts.

It should be noted that the concept of a roundabout encompasses a wide range of configurations varying in size, complexity and traffic loading. When traffic signals are added, the number of design considerations increases, and no two signalised roundabouts will be the same. In other words, there are no 'standard' solutions. There are no hard and fast rules to determine an optimum design, and it still rests with engineers and designers to use their skill and judgement to produce an effective and efficient working solution.

2 SCOPE

This document provides guidance on the following:

- Reasons for considering a signalised roundabout for intersection control.
- Minimum requirements and warrants for the full signalisation of roundabouts.
- Geometric design and safety considerations.
- Traffic analysis considerations.
- Operational and signal phasing considerations.
- Road user considerations, such as specific requirements and facilities for pedestrians, cyclists and heavy vehicles.
- The process to be followed for the selection of signalised roundabout control as an appropriate intersection form.
- Other relevant policies, standards and guidelines that should be read in conjunction with this guideline.
- National and international case studies of signalised roundabouts.

This document covers:

- The full signalisation of large diameter (central island diameter of 50 m or more) roundabouts (or rotaries), where there may be adequate storage within the circulating lanes to facilitate two-phase signal operation.
- The full signalisation of small and medium sized roundabouts (central island diameter of 12 to 50 m), where internal storage on the circulatory lanes is likely to be limited.
- The full signalisation of grade separated roundabout interchanges, such as dumbbell roundabouts and tennis-ball interchanges.
- The partial signalisation of roundabouts, where one or more of the approaches remain under priority control.

A separate Main Roads document, Guidelines for the Analysis of Roundabout Metering Signals (Main Roads, 2015), provides guidance on the analysis of roundabout metering signals (i.e. indirect signal control).

Reference should also be made to 'Towards a Safe System Approach - Selection of Intersection Control Guidelines' (Main Roads, 2025), which provides information to assist practitioners to determining the most appropriate at-grade intersection control solution between a roundabout and a signalised intersection.

3 DEFINITIONS AND ABBREVIATIONS

Definitions are provided below for the terms often used in relation to roundabouts and roundabout signalisation. An example of a signalised roundabout, and some of the common terms used in this document, is shown in Figure 3-1.

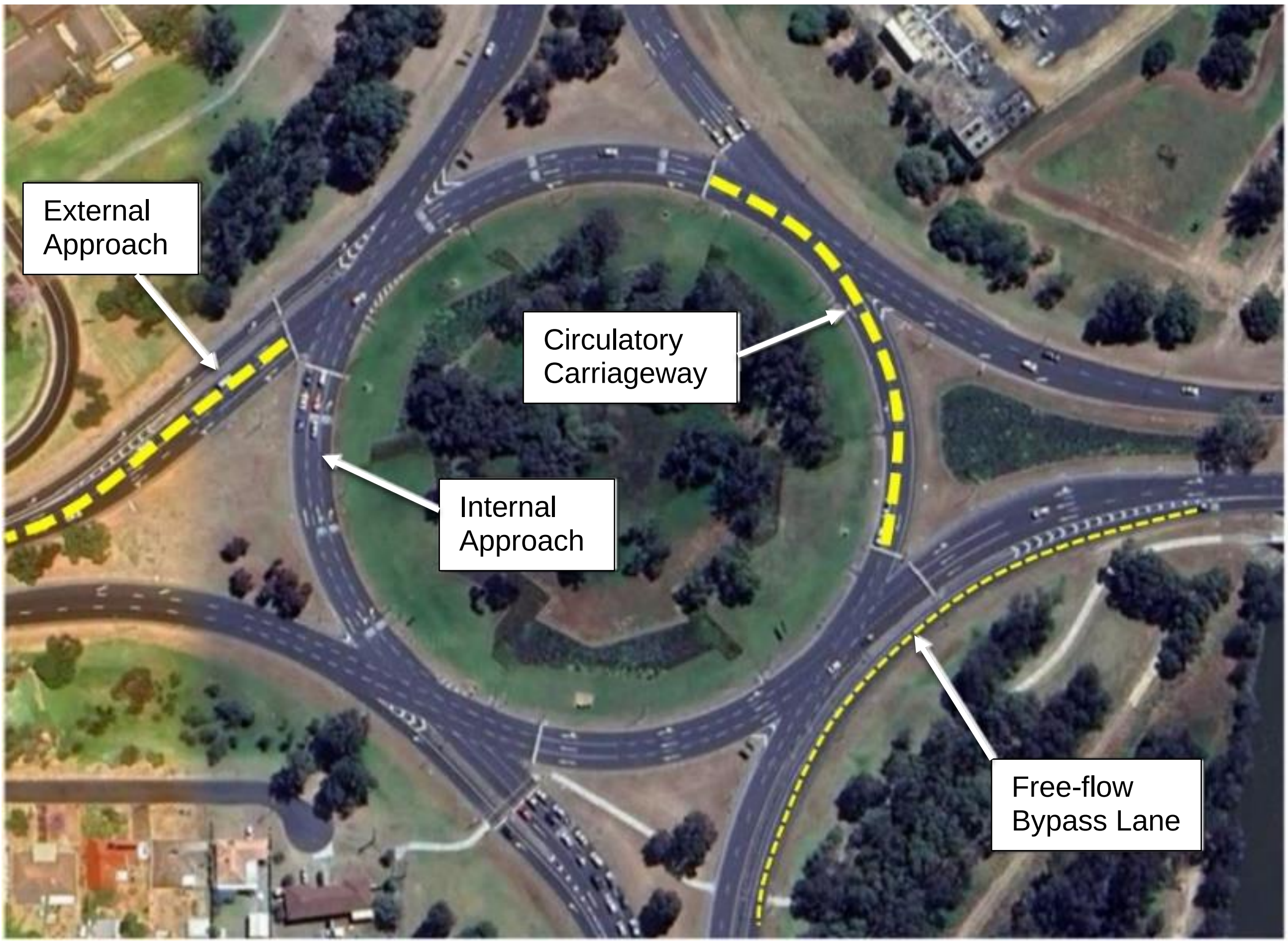


Figure 3-1: Example of a Signalised Roundabout (Eelup Rotary in Bunbury)

Term	Definition
Cycle Time	The required length of time to complete the sequence of traffic signal phases
External Approach	Approach leg / entry arm of the roundabout (approach to the traffic signals).
Full Signal Control (Fully Signalised Roundabout)	All internal and external legs of the roundabout are signalised with direct signal control, with three-phase signals (red, amber, green).
Full-time Signalisation	Signals are in operation 24 hours a day.
Internal Approach	Circulatory carriageway (approach to the traffic signals).
Intersection Intervisibility Zone	A zone identified for the purpose of assessing visibility within the intersection between drivers at each stopline, or between drivers and pedestrians. This zone is applied to avoid the placement of permanent obstructions, that could otherwise restrict the sightlines of drivers to potential conflicts. Refer also Section 8.3.
Large Diameter Roundabout	Roundabouts with central island diameters of 50 m or more.

Term	Definition
Mini Roundabout	A small diameter roundabout that can be installed within an existing priority controlled intersection without the need for road widening. Used as a low cost urban treatment to reduce speeds through the intersection and reduce crashes.
Node	A section of the roundabout where internal and external approach legs meet. In a typical 4-leg signalised roundabout, there will be four signalised nodes within the roundabout.
Partial Signal Control	A signalised roundabout with one or more of the external legs remaining under priority control. Generally, only low-volume external approaches should be considered for remaining under priority control. Refer also Section 9.3.
Part-time Signalisation	Signals are in operation during only part of the day, typically during peak and / or critical periods (e.g. commuter AM and PM peak hours) or when traffic demands on one or more legs reaches a threshold. The rest of the time the roundabout operates on a priority basis. Stop lines must necessarily be set back approximately 20 m from the giveway line.
Roundabout Metering (Indirect Signal Control)	This is where one or more approach legs are metered (signalised), typically with two-aspect signals (red and amber). These signals are set back from the roundabout entry, with the entry itself still operating under normal priority-control rules. Roundabout metering is typically applied to help with unbalanced flow situations, i.e. to provide gaps in the circulating traffic stream, with the dominant approach metered to provide gaps for the downstream approach legs, often only activated during the peak periods. Outside of peak periods, the signals are blank, and normal (priority-control) operation applies. Three-aspect signals may be applied in certain circumstances, e.g. at dumbbell roundabouts such as Tonkin Highway / Dunreath Drive, where the internal leg has no other form of control (i.e. giveway linemarking).
Signalised Roundabout	A roundabout with direct signal control. Both external and internal approach legs are signalised with three-phase signals (red, amber, green), thus directly controlling traffic entering the ‘intersection’ area of the roundabout. Roundabouts can be fully controlled, i.e. all internal and external legs are signalised. At roundabouts with low volumes on one or more of the external approaches, partial signal control may be acceptable, i.e. the low-volume external approach remains under priority control.
Small to Medium Diameter Roundabout	Roundabouts with central island diameters of 12 m to 50 m.
ABBREVIATIONS	
ASD	Approach Sight Distance
ASL	Advanced Stop Line

Term	Definition
CSD	Crossing Sight Distance
DMRB	Design Manual for Roads and Bridges
DOS	Degree of Saturation
FSI	Fatal and Serious Injury (also commonly referred to as KSI – Killed and Serious Injury)
LGA	Local Government Area
LMA	Light Maintenance Traffic Signal Drawing
LMB	Light Maintenance Signage and Pavement Marking Drawing
LOS	Level of Service
Main Roads	Main Roads Western Australia
PCU	Passenger Car Units
ROSMA	The Main Roads Road Safety Management System
SISD	Safe Intersection Sight Distance
TSC	Traffic Signal Controller
VPH	Vehicles Per Hour
VRU	Vulnerable Road Users

Table 3-1: Definitions and Abbreviations

4 ROLES & RESPONSIBILITES

Traffic Signal Approval
Under the Road Traffic Code 2000, Regulation 297, the Commissioner of Main Roads has the sole authority to erect, establish or display, and alter or remove any traffic control signal in WA. Notwithstanding the above, it should be noted that the Commissioner of Main Roads has delegated authority for approval of traffic control signals exclusively to the Executive Director of Network Operations (EDNO).

To this extent, Main Roads' Network Operations Directorate must formally approve all permanent traffic control signal installations, modifications or removals on public roads in WA.
The Main Roads Traffic Signals Approval Policy (Main Roads, 2021) sets out the requirements and approval process that must be followed for new and modified traffic signals in WA.

Design Review and Approval
The geometric design of roundabouts on or intersecting Main Roads controlled (State) roads is subject to the review of Main Roads Road and Traffic Engineering Branch or other relevant Regional Network Manager.

The installation, maintenance and/or removal of signage and pavement marking on publicly accessible roads is subject to the review and approval of the Main Roads Network Operations Directorate. The provision of traffic signs and pavement markings in Western Australia, should be in accordance with Main Roads standard drawings and guideline drawings, pavement marking guidelines, Australian Standard Manual of Uniform Traffic Devices 1742 and Relevant Parts and Austroads Guidelines wherever practical.

Role	Responsibility
Executive Director, Network Operations Directorate	Traffic Signal Approval
Road and Traffic Engineering Branch	Geometric Design Review
Electrical Asset Management	Traffic Signal Design Review
Manager, Traffic Management Services	Signs and Pavement Marking Approval

Table 4-1: Roles and Responsibilities

5 BACKGROUND

5.1 Safe Systems Principles

Western Australia is a signatory to the National Road Safety Strategy 2021-30. The Strategy sets out Australia's road safety objectives over the next decade and aims to reduce the annual number of fatalities by at least 50% and serious injuries by at least 30% by 2030. Western Australia’s Road safety strategy, Driving Change – Road Safety Strategy for Western Australia 2020 – 2030 (Road Safety Commission, 2020), extends on this, with a target of zero fatalities or severe injuries on WA roads by 2050, and also sets a target of to reduce the number of FSI crashes by 50-70% by 2030.

Research has shown that there is approximately a 10% probability of a fatality in a crash between a pedestrian and a car travelling at 30 km/h. Similarly, the critical speed for a right angle crash between two vehicles is 50 km/h and 70 km/h for a head-on crash between two vehicles. This is illustrated in Figure 5-1.

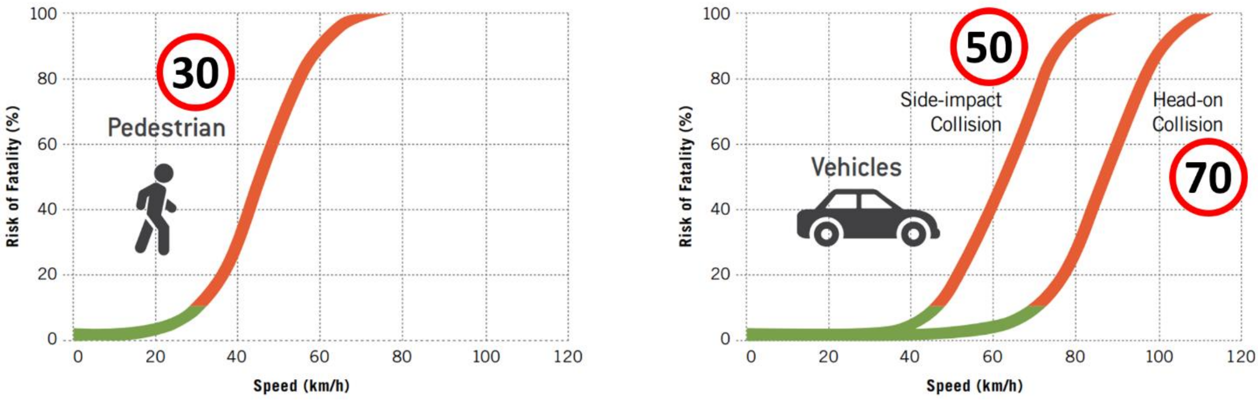


Figure 5-1: Probability of a Fatality for Various Speeds and Crash Types

Based on the above critical speeds, an intersection may be considered as “Safe System compliant” under the following circumstances:

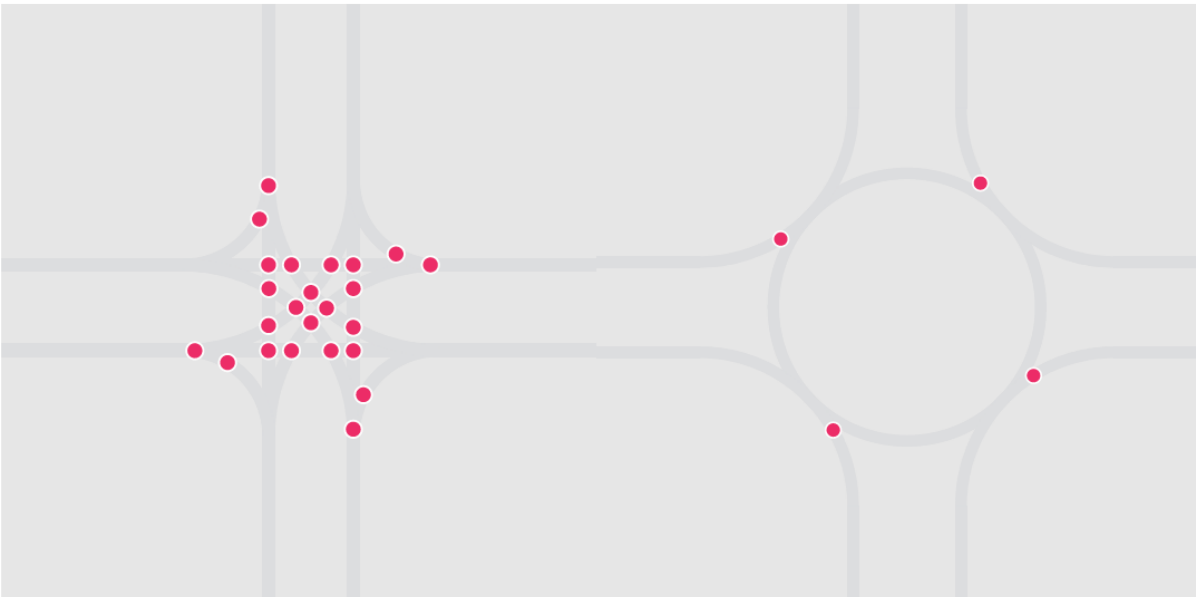
- For intersections with significant[1] vulnerable road user activity, a safe crossing facility shall be provided. Where there is a possibility of a right-angle collision between passenger vehicles, the through-traffic speed should ideally be restricted to less than 50 km/h. Where the crossing facility relies on a driver giving way to a pedestrian (e.g. turning traffic at an intersection, zebra or wombat crossing), the speed of the traffic at the potential conflict point should ideally be restricted to less than 30 km/h.
- For intersections with little or no vulnerable road user activity, the through speed should ideally be restricted to less than 50 km/h, where there is a possibility of a right-angle collision between passenger vehicles.

[1] *The term “significant” is defined in terms of the probability of exposure to conflict and the level of “Place” function within the “Movement and Place” framework. Methodologies to determine whether the number of vulnerable road users is considered “significant’ can be found in Towards a Safe System Approach - Selection of Intersection Control Guidelines (Main Roads, 2025).*

5.2 Roundabouts

Roundabouts have been in use in Australia and New Zealand for many decades. The roundabout is highly effective in improving safety at intersections, and is considered as one of the few Safe System compliant intersection types[2]. The reason for this is that they simplify decision making for road users, encourage appropriate behaviours (motorists have an expectation that slowing down or stopping is required on any approach), reduce points of conflict, virtually guarantee low interaction speeds through geometric design and avoid 90 degree impact angles (Austroads, 2018). With the exception of vulnerable road user, when road users make errors they are unlikely to be seriously injured in the resulting collision.

Roundabouts provide a safer form of control than T-intersections or 4-way intersections and reduce the incidence and severity of crashes. Roundabout layouts satisfy safe intersection design principles in relation to conflict points, minimising the number of conflict points and separating the areas of conflict as demonstrated in Figure 5-2.



Note: Number of conflict points is based on single-lane carriageways. Multi-lane traffic signals and roundabouts will have a much higher number of conflict points.

Signalised intersection
24 conflict points

Roundabout
4 conflict points

Figure 5-2: Conflict Points at Signalised Intersections and Roundabouts

However it is acknowledged that roundabouts present concerns from a pedestrian and cyclist point of view. Austroads, 2015 notes that vulnerable road users make up the majority of the severe crash problem at urban roundabouts, and represent the remaining Safe System gap for this infrastructure element. Figure 5-3 below shows recent crash data (2014 to 2023) collected from a sample of roundabouts and signalised intersections in Western Australia, where almost half of all Fatal and Serious Injury (FSI) crashes at roundabouts involved vulnerable road users (pedestrians, cyclists and motorcyclists). In comparison, at signalised intersections only 13% of FSI crashes involved vulnerable road users.

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[2] *Roundabouts are considered a Safe System Option ("primary" or "transformational" intersection treatment) along with "close intersection", grade separation, low speed environment / speed limit and raised platform (Austroads, 2018)*

Figure 5-4, based on 2013 data from urban roundabouts in Victoria (Austroads, 2015) further highlights the severity of pedestrian casualty crashes, at 47% (i.e. 47% of recorded casualty crashes at roundabouts resulted in fatality or serious injury), compared to the average for all casualty crashes recorded of only 30%.

In-depth analysis of the crash data by Austroads 2015 highlighted that 83% of severe bicycle crashes and 36% of severe motorcyclist crashes at roundabouts were adjacent direction crashes (19 and 9% of all severe crashes at roundabouts respectively), with the key crash cause for both user groups, entering drivers not seeing/acknowledging the two-wheeler already within the roundabout. It proposes that current roundabout designs provide entry speeds which are too high for vulnerable road users. Proposed areas for improvement should seek ways to reliably reduce approach and entry speeds to less than 30 km/h to close the Safe System gap for all users. The full signalisation of roundabouts offers one potential treatment to closing this Safe System gap.

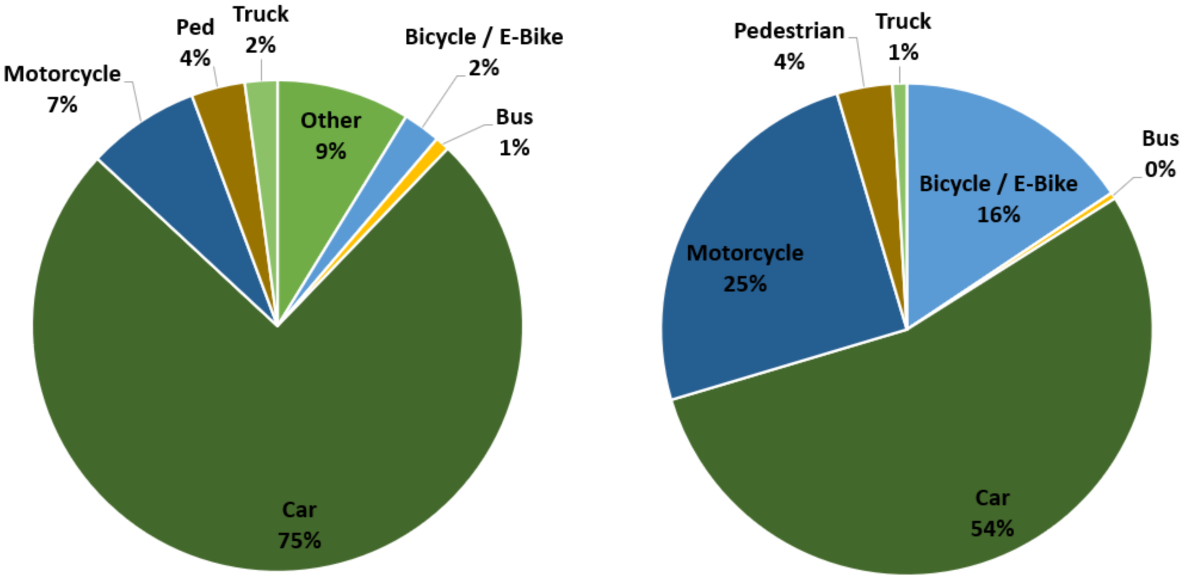

Figure 5-3: FSI Crashes at Traffic Signals (left) and Roundabouts (right) by Road User Type (based on 2014 to 2023 data from all intersections sites in W.A. where a FSI crash has been recorded, Source: Urbsol, 2024)

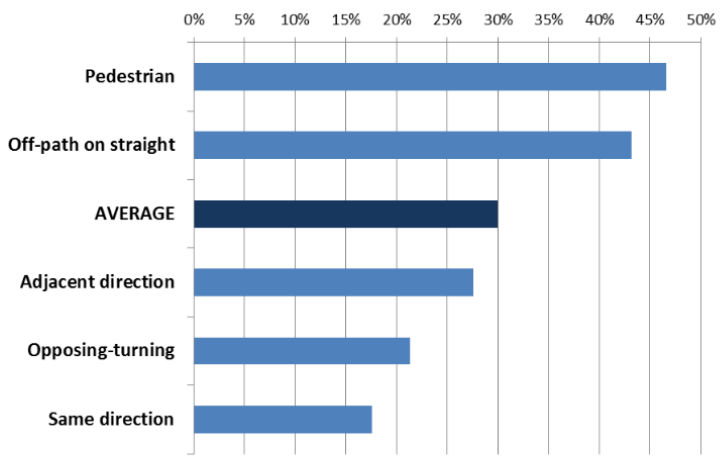

Figure 5-4: Average Severity of Different Types of Casualty Crashes at Urban Roundabouts (based on 2013 data from Victoria, Source: Austroads, 2015)

5.3 Signalised Roundabouts

From a potential crash severity point of view, a signalised roundabout can fundamentally be considered as a roundabout, as it offers most of the geometric design benefits of regular roundabouts (low entry speeds, moderate impact angles) (Austroads, 2015). However roundabout signalisation can help resolve the remaining Safe System gaps in this intersection form, especially when combined with low entry and circulating speeds. Drivers would no longer need to spot and give way to two-wheeler riders, and this may reduce the incidence of adjacent direction impacts (Austroads, 2015).

(Austroads, 2017a) has noted that signalised roundabouts provide the greatest alignment with Safe System objectives:

"The opportunity for a crash to occur should be also diminished, as roundabouts have less conflict points than a comparably-sized traditional signalised intersection (opposing-turning and adjacent direction are combined). Signalised roundabouts have an additional advantage over typical roundabouts: the priority decision is simplified from gap acceptance to obeying the red signal. This should further reduce the likelihood of a crash occurring, especially at larger multilane sites. The severe (FSI) injury probability for pedestrians and other vulnerable road users would be greatly reduced as well, although not minimised. The likelihood of pedestrian and cyclist crashes could be further reduced by use of signalised crossings, cycle lanes/storage boxes, staged or offset crossings or bypasses."

Signalised roundabouts have been used successfully throughout the world for many decades, with some of the experiences of individual countries summarised below.

5.3.1 UK Experience in Signalised Roundabouts

Signalisation of roundabouts is used extensively in the United Kingdom to improve capacity, reduce delays, reduce crashes and address pedestrian and cyclist difficulties. There has been a rapid increase in the installation of signal controlled roundabouts in the UK since the early 1990s. A 2006 survey of 47 authorities in the UK (Department for Transport, 2009) collected information on 239 signalised roundabouts, and identified a number of trends in the reasons for signalisation and the type of control used, including:

- The primary reasons for signalisation (of existing roundabouts) are queue control, increased capacity and accident reduction.
- Approximately half of all surveyed sites are fully signalised.
- Full-time control is widely accepted as the preferred control arrangement.
- TRANSYT and LinSig are some of the primary tools used for appraisal of the signals.

Local Transport Note 1/09 - Signal Controlled Roundabouts (Department for Transport, 2009) was developed to assist those involved in the design and operation of signalised roundabouts by identifying the issues that need to be addressed and providing guidance on how they can be dealt with. The UK Design Manual for Roads and Bridges provides standards for the design of signalised roundabouts, primarily covered in the Design Manual for Roads and Bridges (DMRB), CD116 - Geometric Design of Roundabouts (National Highways, 2023).

While the above guidelines are valuable resources for designers and engineers in WA, it should be noted that standards and regulations do differ. Moreover, the fleet types in the UK differ substantially from Western Australian fleet types: in the UK trucks are less than 50 tonnes gross, whereas Western Australia can have trucks of up to 148.5 tonnes gross, lengths are different and driver training and behaviour is different. The Main Roads guidelines (this document) have aimed to incorporate the findings from UK experience where considered applicable and appropriate to our driving environment.

5.3.2 United States Experience in Signalised Roundabouts

The United States has limited experience with roundabout signalisation. The U.S. Guideline "Roundabouts: An informational Guide" (Federal Highway Administration, 2000) states: "Roundabouts should never be planned for metering or signalisation. However unexpected demand may dictate the need after installation. Full signalisation should … only be considered as a retrofit alternative resulting from unanticipated traffic demands. Other feasible alternatives should also be considered, such as flaring critical approaches, along with the associated widening of the circulatory roadway; converting a large-diameter rotary to a more compact modern roundabout form; or converting to a conventional signalized intersection".[3] However recent accessibility guidelines (Accessibility Guidelines for the Public Right-of-Way, US Access Board, 2023) mandates requirements for all new or altered pedestrian facilities, in accordance with the Americans with Disabilities Act and Architectural Barriers Act, including: "each multi-lane segment of the roundabout containing a crosswalk shall provide a crosswalk treatment consisting of one or more of the following: a traffic control signal with a pedestrian signal display; a pedestrian hybrid beacon; a pedestrian actuated rectangular rapid flashing beacon; or a raised crossing. This requirement may see an increase in signalised roundabouts in the U.S. in the future.

5.3.3 New Zealand Experience in Signalised Roundabouts

New Zealand first implemented signalisation of roundabouts in 2008, at Maungatapu, Tauranga. Signalisation was implemented as a less expensive solution to the previously proposed grade separation solution, and was found to be highly successful. Further information is provided in the case studies in Appendix A. New Zealand now has a number of signalised roundabouts, including at a recently constructed grade separated interchange, the Bayfair roundabout, also located in Tauranga, shown in Figure 5-5 below.

Figure 5-5: Visualisation of the Bayfair Grade-Separated Roundabout featuring traffic signal control (Source: NZTA - https://www.nzta.govt.nz/projects/baypark-to-bayfair-link/sh2-bayfair-roundabout/)

[3] *The 2010 update to this guideline (NCHPR, 2010) removes most of this guidance, and simply states "A detailed discussion of full signalization is outside the scope of this document."*

5.3.4 Australian (East Coast) Experience in Signalised Roundabouts

Currently there are only a handful of examples of signalised roundabouts across Australia, and these have had varying success. The Railway Roundabout in Hobart has been signalised for over 35 years, however has had a relatively poor crash rating, ranking as one of the worst crash hot-spots in Tasmania in 2015. This is likely attributable to a number of factors, including the significant growth in demand through the intersection, with minimal upgrades in since its construction, as well as the complexity of closely spaced signalised intersections on all downstream legs. The five year crash data to 2018 shows that all crashes were non-FSI crashes, with most being property damage only.

New South Wales’ first fully signalised roundabout at Oak Flats south of Wollongong, at the interchange of Princes Motorway and New Lakes Entrance Road, was opened in 2021, however regularly experiences extensive queuing and delays. Signal timing improvements have since been implemented, and additional civil improvements are proposed for delivery in 2024. Crash data for the 5-year period to 2023 shows that since the roundabout was signalised (mid 2021), there have been only small number minor (non-casualty) crashes at the roundabout. In comparison, prior to signalisation, there have been moderate and serious injury crashes.

Other examples of signalised roundabouts vary from a small diameter roundabouts (30 m) in Tullamarine Victoria, to a 110 m ‘square-about’ in Maroochydore, Queensland. The signalisation of one of Canberra’s most dangerous intersections, at Barton Highway and Gundaroo Drive, in 2016, has proven very successful, with crashes being reduced by approximately half. Additional details of this intersection are provided in Appendix A.

5.3.5 Western Australia Experience in Signalised Roundabouts

Currently in Western Australia there is one fully signalised roundabout; Eelup Rotary in Bunbury. The signals were switched on in 2013, and have been successfully operating since then. The background and success of this signalised roundabout is detailed in Appendix A. The “Tennis Ball” interchange at Roe Highway / Berkshire Road in Forrestfield, W.A., is also an example of a signalised intersection that applies many of the geometric benefits of a roundabout, as discussed in Section 8.12. There are also a number of locations with roundabout metering in Perth that have been operating successfully for a number of years, including Point Lewis Rotary in Perth, Murdoch Drive / Farrington Road in Murdoch, Tonkin Highway / Dunreath Drive and Sugarbird Lady Road / Airport Drive in Perth Airport.

6 REASONS FOR CONSIDERING SIGNALISED ROUNDABOUTS

6.1 Safety

(Austroads 2015) notes that the main safety benefit of a signalised roundabout would come from simplification in assignment of right of way. A signalised roundabout may be more safety-effective at large, multilane roundabouts, where gap acceptance is more prone to error (e.g. multiple lanes and directions of conflicting vehicles, higher circulating speeds). The main types of crashes affected would be side-swipe (adjacent direction) and rear-end. This report also notes that the "legibility of more complex roundabout sites may be improved by provision of signals."

Other safety benefits of signalising a roundabout include:

- Reduction in crashes resulting from poor judgement of gaps in circulating traffic.
- Reduction in the incidence of rear-end crashes between vehicles waiting to join the roundabout.
- Ability to provide pedestrian crossing facilities with active control.
- Increase in cyclist and motorcyclist safety as motorists would no longer need to spot and give way to two-wheeler riders.

Roundabouts with poor sight lines from one or more of the approach legs, such as those impacted by concrete bridge abutments, high parapets, or other constraints (building structures, large trees), may also benefit from signalisation.

A before and after study undertaken in the UK (Transport for London, 2005) looked at casualty collisions at 10 at-grade roundabouts and 10 grade separated roundabouts, based on the collision record 3 years prior and 3 years following their conversion from priority controlled roundabouts to signalised roundabouts. This showed a significant decrease in collisions for the at-grade roundabouts, at 28% for total number of collisions, and an 80% decrease in collisions involving cyclists. The benefits at grade separated roundabouts were not as significant, with only a 6% for total number of collisions, however they did show significant benefits for collisions involving pedestrians, with a 59% reduction.

6.2 Pedestrian and Cyclist Access

When compared to priority controlled roundabouts, signalised roundabouts may offer additional benefits to cyclists and motorcyclists, especially when combined with low entry and circulating speeds. Drivers would no longer need to spot and give way to two-wheeler riders, and this may reduce the incidence of adjacent direction impacts (Austroads 2015). On routes with high cyclist demands, traffic signal priority could be provided for cyclists, such as cyclist advance stop lines, which would further enhance their visibility on the road, and advanced green lights for cyclists (refer Section 9.2) to give cyclists a head-start entering the intersection.

One of the primary benefits of signalised roundabouts for pedestrians is the ability to provide signalised crossings across external and internal approach legs to the roundabout. Pedestrian call button facilities can be installed at these crossings to enable prioritisation for pedestrian movements. The short cycle times typically adopted for signalised roundabouts is also favourable for pedestrian access. Combined with pedestrian paths within the roundabout (between the internal leg crossing points, this can provide signalised access for all pedestrian routes across a roundabout. For high demand routes, or where the provision of pedestrian paths within the roundabout is not possible, pedestrian crossing facilities (signalised, zebra or wombat crossings) should also be considered for departure legs (refer Section 8.4).

6.3 Congestion / Capacity Issues

Priority controlled roundabouts offer an excellent means of sharing the available capacity by separating and managing conflicting movements within a single intersection. However, these 'give-way' roundabouts can break down when:

a) one or more dominant movements take up an unequal share of the available capacity; and
b) a small but persistent volume of traffic passes in front of one of the roundabout approach legs where a very high volume of traffic is trying to egress.

In other words, one can immediately achieve more equitable access and a better practical reserve capacity for the intersection as a whole through signalisation (Chard, Thomson and Bargh, 2009).

In circumstances where several roundabout approaches are performing poorly for extended periods, and a conventional signalised intersection is inappropriate, a roundabout may be fully signalised (Austroads, 2023a). Signalisation may also be considered if an existing roundabout is performing poorly in terms of delay on several approaches. The benefits that might be derived from signalisation should be investigated through traffic analysis (Austroads, 2020b). Alternative means of capacity improvement, such as roundabout metering, should also be investigated as discussed in Section 7.5.

New land use developments might require additional accesses to be added to existing roundabouts, or result in increased traffic which might trigger the need to consider the addition of signals (Department for Transport, 2009).

In Western Australia, the primary reason for signalising the Eelup Rotary in Bunbury was to resolve existing capacity issues, especially with respect to heavy vehicles; road trains were finding it increasingly difficult to pick gaps in the circulating traffic. It was also designed to address the existing high crash rates, and better manage heavy tidal flows and congestion during peak holiday periods. The proposed design also aimed to better define traffic turn lanes within the intersection, to reduce poor lane choice and lane changing within the roundabout. The signalisation of this roundabout has been an outstanding success, and has enabled the roundabout to operate with adequate capacity for more than 10 years since signalisation. Further details on the success of signalisation at Eelup Rotary is provided in Appendix A.

6.4 Grade Separation

A grade separated interchange is a significant capital investment, and should be planned and designed to service the forecast demands for the foreseeable future. Main Roads typical practice is to design grade separated interchanges based on the 20 year forecast demand, often with allowance for the ultimate land use and traffic demand (i.e. assuming full build out of surrounding land use and road network beyond the 20 year horizon). While extensive investigation and traffic analysis is undertaken to ensure a robust outcome, estimating traffic demands and patterns so far into the future can be extremely challenging and prone to change. Roundabouts and dumbbell roundabouts are often considered to be suitable options for grade separated interchanges, particularly where adequate space is available. They have lower operational costs and offer greater vehicle safety. However the efficient operation of roundabouts can be highly dependent on flow balance, and are prone to capacity constraints where there is an imbalance of traffic flows, or continual flow on the circulating carriageway. Unplanned land use or transport network changes can result in traffic flow patterns quite different to the demands that the intersection was designed for, which can quickly lead to capacity issues and congestion. Priority controlled roundabouts are particularly sensitive to these changes in flow patterns, as they don't have the inherent adaptability of traffic signals, where both lane allocation and green-time allocation can be adjusted to reflect actual demand.

Hence at grade separated interchanges, where a roundabout is the preferred form of intersection control, it is Main Roads preference that provision be made for future conversion to a signalised roundabout.

6.5 Cost Considerations

The cost of implementing a signalised roundabout as an upgrade at an existing roundabout to increase capacity should be low, when compared with removal and upgrade to a large signalised intersection (Austroads, 2018). In the interest of providing value for money and the need to stretch road funding further, asset managers are constantly looking for ways to 'sweat the asset'. As a result, improvements to the safety and capacity of any intersection should ideally start with modifications to the existing layout. Signalisation or metering of existing roundabouts is a practical and cost-effective option that can be considered, in addition to exploring more expansive upgrades such as major layout modifications, replacing a roundabout with traditional signals or grade-separation.

6.6 Other Considerations

Other benefits to roundabout signalisation (when compared to priority controlled roundabouts) that should be considered in any proposal include:

- Improvement to travel time consistency.
- Opportunity to link the signal operation in SCATS with upstream or downstream traffic signals, to improve coordination and signal progression, particularly on the main arterial road.
- Ability to prioritise specific legs or movements, creating more balanced flows and regulating traffic patterns.
- Ability to prioritise specific road users, such as freight.
- Ability to manage and facilitate dominant traffic movements that change by time of day (AM / PM peak) or for seasonal differences.
- Opportunity to improve the driver legibility and safety of overly complex intersections, such as existing signalised or priority controlled intersections with more than four approach legs.
- Provision of greater resilience to growth or fluctuations in traffic demand.
- The ITS provisions at traffic signals allow for better live monitoring from the Main Roads Road Network Operations Centre, allowing for faster response times and management of incidents, and diversion of traffic flow can be facilitated through the adjustment of traffic signal timings.
- Ability to better manage traffic flows onto a freeway entry ramp, to help with queue management, particularly where a roundabout is installed upstream of a freeway operating with Coordinated Ramp Signals (CRS) (though it should be noted that current Main Roads practice is to operate ramp meters and upstream traffic signals independently of each other).

At the same time, there are potential disbenefits to signalised roundabouts that should also be considered in any proposal:

- Confusion with other neighbouring signals.
- Added complexity, e.g. if additional flaring, lane changes and spiral line marking are required to provide additional storage for specific turning movements.
- Overall increases in traffic delay during off-peak periods.
- Operating and maintenance costs.

Signalisation of roundabouts might not be the most appropriate solution under the following conditions:

- Constrained urban environments, or where impact on land and other physical constraints prevents an adequately-sized roundabout to be constructed, especially when internal storage is required for an efficient operation, or when auxiliary/free flow left slips impact nearby sites or accesses.
- Along high-priority public transport routes.
- Where there is significant uncertainty in future land uses surrounding the roundabout.
- Where significant U-turning traffic currently exists or is projected, which could be triggered by surrounding network impermeability or access restrictions at adjacent land uses (e.g. shopping centres or similar developments with left-in / left-out access onto the main road).
- Where there is uneven or poor lane utilisation due to downstream destinations/access points (such as at major shopping centres.

Signalisation of roundabouts should not be the only option considered in a proposal. Alternative options are discussed in Section 7.5.

7 CRITERIA FOR ASSESSING THE SUITABILITY OF A SIGNALISED ROUNDABOUT

Table 7-1 provides an overview of some of the important criteria to be considered when assessing the potential suitability of a signalised roundabout. All aspects of the roundabout should be considered, including geometric, road environment / surrounding land use, road users and traffic demand characteristics; while some criteria at an individual intersection may be favourable to signalisation, other criteria may preclude it from being signalised, and hence the table should be used as a preliminary guide only. Further preliminary assessment guidance is provided in this section, considering total intersection demand, right turn demand and internal storage requirements, as well as alternative treatments that should be considered in conjunction with or instead of full signalisation. Detailed discussion on geometric, operational and traffic considerations is provided in Sections 8 to 10.

Criteria to Consider	Potential Signalised Roundabout Suitability	Comments
Geometry		
Central island diameter ≥ 50 m	Very High	Likely to operate under two phase cycle operation at each signalised node, and provide adequate internal storage.
Central island diameter between 20 m and 50 m	Moderate	May be appropriate with shorter cycle times, additional circulating lanes, or more than two phase operation to accommodate right turn demand. Might not be appropriate where there is a large number of heavy vehicles, where internal storage requirements for large trucks cannot be met.
Grade separated interchanges (including oval, circular, dumbbell, tennis-ball)	Very High	Will likely require three to four phase signal operation due to limited storage on short internal legs.
5 leg intersections	High	Signage for road users becomes more complicated within the roundabout, however there are examples of 5 leg signalised roundabouts operating interstate and worldwide.
3 to 4 legs on intersection	Very High	Fully signalised operation on three-legged roundabouts is less common, although they can be partially signalised at only some nodes depending on flow scale and balance (or part-time signalisation or roundabout metering could be considered instead).
Unbalanced number of lanes on approaches and departures , or need for double right turn lanes	Very High	Signalised roundabouts can limit the impact of spiral linemarking, which often leads to driver confusion at unsignalised roundabouts. Flaring on entry legs with adequate signage and lane marking can also facilitate wayfinding.

Criteria to Consider	Potential Signalised Roundabout Suitability	Comments
Single lane roundabout	Moderate / Low	Depending on the issue being addressed, other treatments are more likely to be appropriate, e.g. converting to a two lane roundabout to address capacity constraints, or approach leg geometric improvements to address safety issues. Refer also Section 7.5.2.
Road Environment / Surrounding Land Use		
Activity Centre	High	Has a larger footprint to a conventional signalised intersection, likely resulting in less convenient and direct access for pedestrians and cyclists. However preferred to priority-controlled roundabouts.
Urban Area	Very High	Provides a good balance between road safety and access for all road users, and capacity / efficiency for traffic.
Rural Area	Moderate	Traffic signals might not be expected on rural routes.
High place value (on the Movement and Place Framework)	Moderate	Has a larger footprint to a conventional signalised intersection, likely resulting in less convenient and direct access for pedestrians and cyclists.
Road Users		
Significant[1] pedestrian demand	Very High	Significant benefits to pedestrian access and safety.
Significant[1] cyclist demand	Very High	Significant benefits to cyclist access and safety. Particularly beneficial where many cyclists share the road space to travel through the roundabout.
A large number of heavy vehicles / multi-combinational heavy vehicles	Very High	Signals are far preferred by heavy vehicle drivers as they don't need to "pick a gap" in the circulating traffic.
High frequency bus routes or bus lanes required along route	Low	Difficult to maintain bus lanes through intersection.
Traffic Demand Characteristics / Operation		
High volume of right turning demand	Low	Only likely to be suitable with larger diameter roundabouts where adequate storage is achievable.
Low demand on one leg	High	Opportunity to retain existing priority control on low-demand legs.
Unbalanced traffic flows	Very High	Also consider roundabout metering.
Nearby signalised intersections or metered freeway entry ramps	High	Signal coordination between closely spaced intersections / metered freeway entry ramps (although isolated operation may be more efficient in some cases).

Criteria to Consider	Potential Signalised Roundabout Suitability	Comments
Nearby priority-controlled roundabouts	Moderate	Potential for queuing from downstream uncontrolled intersections to adversely impact signalised roundabout.
Existing Roundabout – Operational Issues		
High approach or circulatory speeds	High	Signals should reduce the likelihood of poor driver judgment of gap acceptance, and result in an average reduction in circulatory speeds.
Poor safety performance	High	Particularly effective for existing safety issues with VRUs.
Traffic congestion issues (significant delay, poor reliability, queue spillback into upstream intersections)	Very High	Signal timing can be optimised to cater for heavy movements. Multiple signal plans can also provide flexibility in operating throughout various periods with different flow scales, balances and profiles.

[1] Note: Methodologies to determine whether the number of vulnerable road users is "significant' can be found in Appendix F of 'Towards a Safe System Approach - Selection of Intersection Control Guidelines' (Main Roads, 2025)

Table 7-1: Criteria for Assessing the Suitability of a Signalised Roundabout

7.1 Conversion of Existing Roundabouts to Signalised Roundabouts

For existing roundabouts, one or more of the following criteria must be met before a signalised roundabout may be considered:

- High circulatory speeds (greater than 30 km/h).
- Poor safety record, e.g. a high-risk ROSMA rating (i.e. black).
- Overall level of service or level of service on a particular approach of LOS F (i.e. delay of greater than 70 s).
- Extensive queuing (e.g. more than 500 m) on one or more legs during peak periods.
- Queuing from a downstream intersection regularly spilling back into the roundabout and blocking access.
- Queuing from the roundabout regularly spilling back and impacting operation of an upstream roundabout or signalised intersection, or extending beyond an off ramp and impacting operation of an upstream freeway or highway.
- There is significant pedestrian demand and pedestrians are unable to cross (especially downstream legs) due to insufficient crossing sight distance or insufficient gaps in the traffic and the provision of a priority pedestrian crossing (zebra, wombat or signalised pedestrian crossing) is not a safe or practical option.

7.2 Installation of a Signalised Roundabout at a New Intersection Site

The signalisation of roundabouts is often applied to existing roundabouts. The case studies in Appendix A are examples of where existing roundabouts have been signalised to resolve specific issues, including safety, capacity and restricted access. However there may be instances where a new (green-fields) intersection site is a candidate for installing a signalised roundabout. For new sites, practitioners should first refer to Towards a Safe System Approach - Selection of Intersection Control Guidelines' (Main Roads, 2025), which provides information to assist in determining the most appropriate at-grade intersection control solution between a roundabout and a signalised intersection. If following the methodology outlined in that guideline does not provide a clear outcome, or both intersection options are considered feasible and appropriate, then a signalised roundabout may be a potential candidate. The factors outlined in this section should be considered, along with the geometric design considerations outlined in Section 8 the operational considerations outlined in Section 9, and the traffic analysis considerations outlined in Section 10. If the geometric requirements are met, adequate intersection capacity is achieved, and the benefits of a signalised roundabout can be demonstrated over alternative forms of intersection control, then installation of a signalised roundabout may be an appropriate solution. Consideration should also be given to installing a priority controlled roundabout as a first stage, with provision for conversion to a signalised roundabout in the future.

7.3 Roundabout Capacity – Preliminary Check

The preliminary check outlined below should be applied at each entry point to the roundabout to determine if the combined entry flow and circulating flow for each lane are within the typical saturation flow limits, considering the inter-green phase requirements and practical degree of saturation. This is based on the methodology outlined in Local Transport Note 1/09 - Signal Controlled Roundabouts (Department for Transport, 2009).

Individual signalised nodes on a roundabout will usually operate as simple two-stage signals. Once a draft lane flow diagram has been drawn up, a simple check will show if a node will have sufficient capacity. If the highest individual lane flow from each of the two stop lines (i.e. critical lanes) are added together, then a total less than about 1500 pcu/h would indicate that there is likely to be sufficient capacity. This is based on an assumed cycle time of 60 seconds, 5 second inter-greens, a lane saturation flow of 1900 pcu/h and a degree of saturation of 90 percent.

Figure 7-1 below provides a high-level guide to the hourly capacity for roundabouts with one, two and three circulatory lanes, assuming conventional movement allocation[4] (based on the sum of all external approach demands). As shown in this figure, as the proportion of right turn demand from each approach (from one or more legs) increases, the effective capacity of the total roundabout decreases. This figure assumes minimal heavy vehicle demand, a 60/40 split of traffic on each leg (tidal peak / non-tidal peak demand), two-phase signal cycle and an assumed cycle time of 60 seconds. For intersections with demand above that shown in this figure, an additional lane may be required for one or more of the approaches and associated internal legs to provide adequate capacity. A worked example demonstrating the use of this Figure is provided in Appendix B.

If a signalised roundabout is likely to be suitable, lane flow diagrams and/or traffic modelling in accordance with Section 10 should be undertaken to demonstrate adequate capacity and operational performance for the peak periods can be achieved.

[4] *Through movements allowable on the two approaching lanes, with the left and right movements allowable only on the kerbside and median lane respectively.*

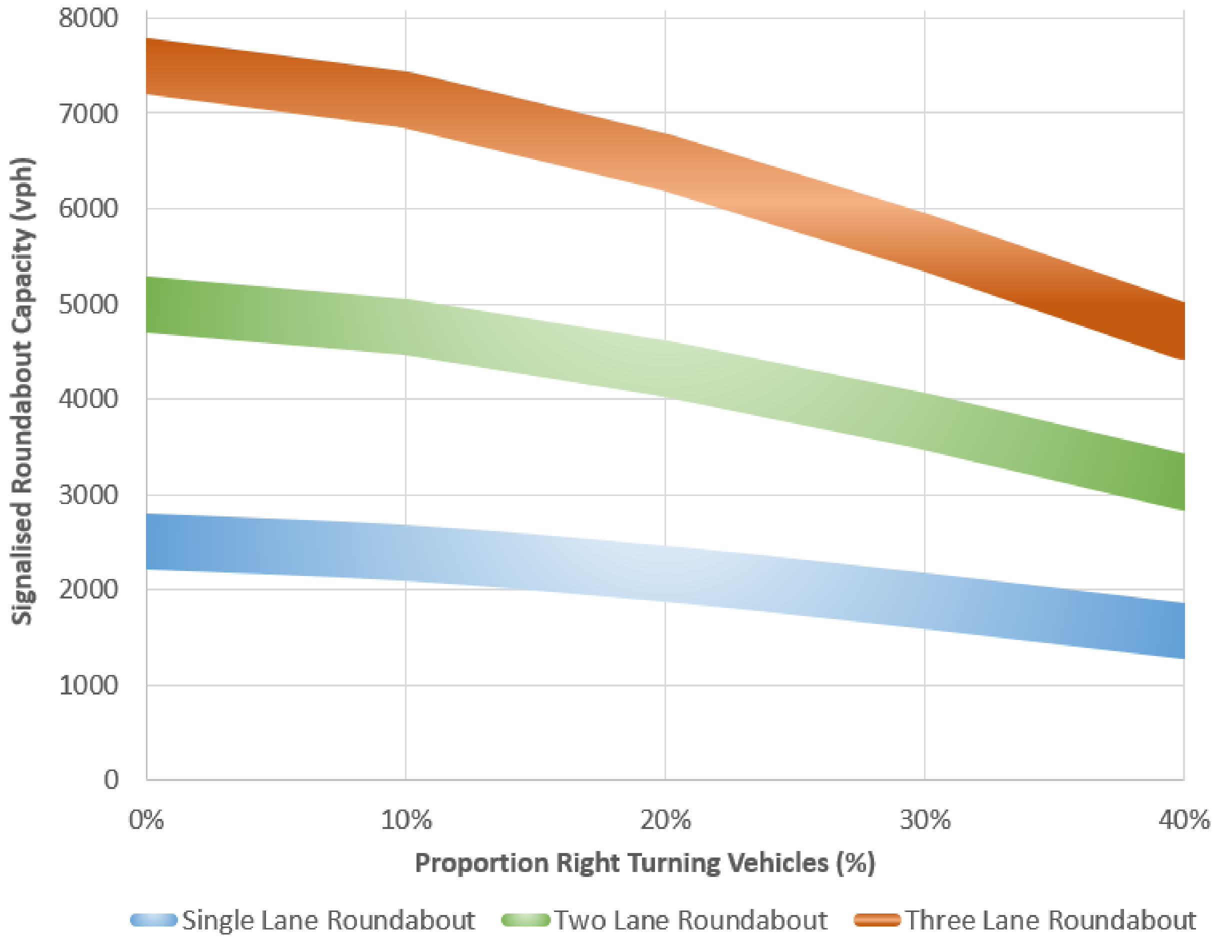

Figure 7-1: Indicative Hourly Capacity of a Signalised Roundabout relative to Right Turn Demand (vph)

7.4 Geometric Design – Preliminary Assessment

To operate effectively under a conventional signal phasing, a signalised roundabout requires adequate internal storage for right turn demand to prop between intersections. In general, a minimum of 20 m storage should be provided on all internal approach legs, sufficient to cater for a Right of Way vehicle (19.0 m semi-trailer). Where the roundabout is on a RAV network, larger diameter roundabouts are required to meet adequate storage requirements, as discussed in Section 8.5.

As a rule of thumb, the recommended central island diameter and associated internal storage for a signalised roundabout is as follows:

- 5 leg roundabout – Diameter of 80 m or more.
- 4 leg roundabout – Diameter of 50 m or more.
- 3 leg roundabout – Diameter of 40 m or more.
- Roundabouts on RAV routes – minimum internal storage to cater for the design vehicle (typically 70 m diameter roundabout for RAV 2 to 4 routes, and 80 m diameter for RAV 5 routes and above).

Figure 7-2 shows the indicative maximum right turn demand for a single approach leg (based on the approach with the greatest demand) relative to the roundabout central island diameter, in order to provide adequate storage for two-phase signal operation. This is based on the stacking space available inbetween intersection nodes on the roundabout, for a range of cycle times (40 seconds to 80 seconds). This should be treated as an indicative guide only, and is dependent on heavy vehicle composition, lane utilisation, the number and geometry of approach legs. Additional storage may be achieved by installing an additional circulatory and flaring on entry lanes, or dedicated storage lane for right turn traffic, or a third signal phase for heavy right turn movements. A worked example demonstrating the use of this Figure is provided in Appendix B.

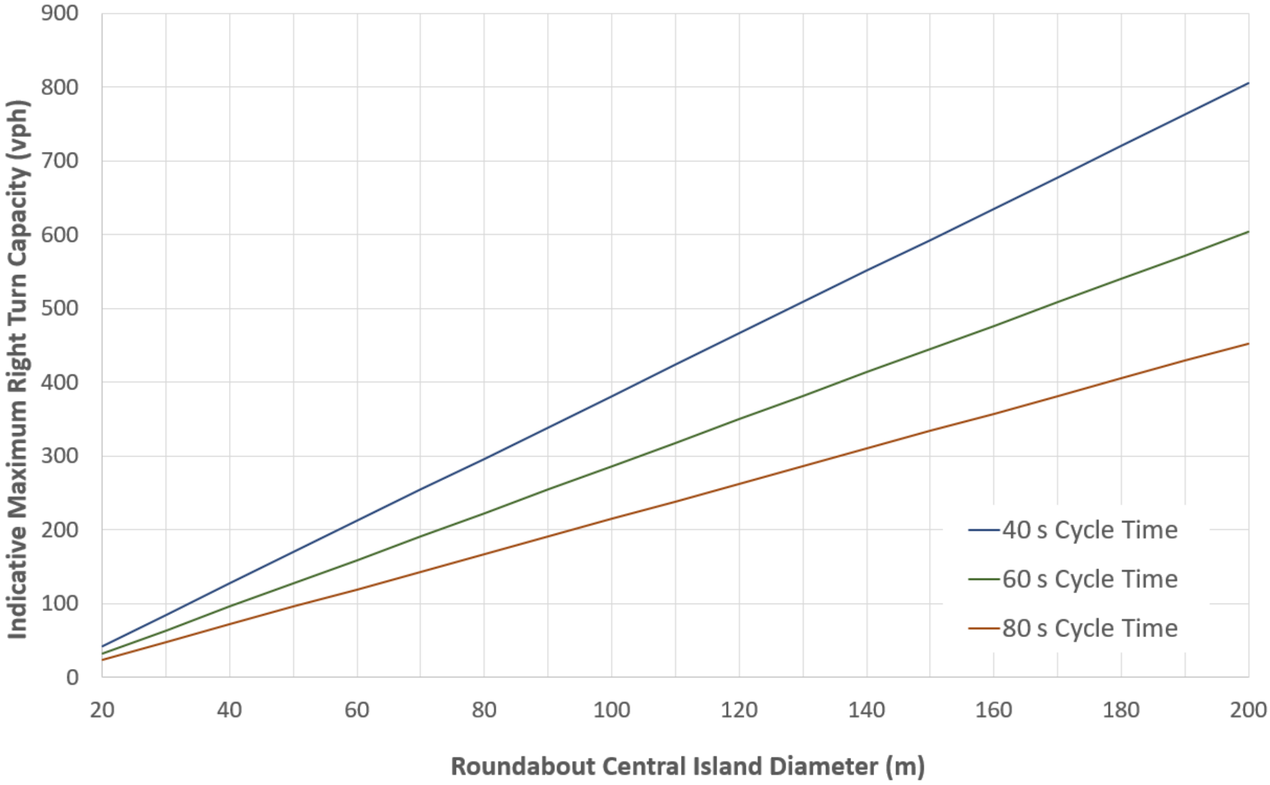

Figure 7-2: Indicative Central Island Diameter of a Signalised Roundabout with 2 Circulating Lanes, to Provide Adequate Storage for Right Turn Demand (vph), based on Two Phase Signal Operation

If the central island diameter is likely to be suitable to cater for the forecast right turn demand, traffic modelling in accordance with Section 10 is required to demonstrate adequate capacity and operational performance for the peak periods can be achieved.

Where the internal storage requirements cannot be met, alternative geometric layouts may be considered, such as dumbbell or tennis-ball layouts, where storage for some right turn movements is provided on the external legs, (as discussed in Section 8.11), or alternative signal phasing that avoids all internal storage (as discussed in Section 11).

7.5 Alternative Means of Improving the Performance of Roundabouts without Installing Signals

Roundabout signalisation should not be the only option considered for treating existing capacity, safety or operational issues. The following alternative options should also be given adequate consideration:

1. External approach leg geometric improvements (horizontal and vertical) to reduce vehicle speeds through the roundabout and improve road user safety.
2. Convert a single lane roundabout to dual lane[5].

[5] Single lane roundabouts, which may already offer a suitable cycling environment, would likely be converted to two lane roundabouts before considering signalisation (Waka Kotahi: https://www.nzta.govt.nz/walking-cycling-and-public-

3. Install free-flow left slip bypass lanes (where there is available space).
4. Roundabout metering, particularly where there is an imbalance of flows at one approach.

The hierarchy of treatments would generally be considered in the order listed above, with full signalisation if the above options are not deemed suitable at treating the existing issue, or cannot be achieved due to geometric or other physical constrains. The signalisation of roundabouts may also be considered in conjunction with one or more of the above options if they cannot treat the existing issue alone.

These options are discussed in more detail below.

7.5.1 External Approach Leg Geometric Improvements

Geometric improvements to an approach leg will only treat existing safety issues, and are unlikely to make any significant improvement to operational or capacity issues. The most effective geometry improvement is the installation of pre-deflection through successive reverse horizontal curves of reducing diameter to gradually slow vehicle speeds approaching a roundabout. This is Main Roads preferred method of speed reduction, particularly on high-speed routes. Refer to the Main Roads Guideline Drawing, Roundabout Speed Reduction Approach Treatments – Reverse Curves, for geometric design set out information. Alternative treatments include vertical deflection on the external approaches (road hump, raised plateau or raised pedestrian crossing), or treatments that give the perception of lane narrowing on the approach, including long island medians or diagonal pavement marking, which can be effective at reducing vehicle speeds on the approach to a roundabout.

7.5.2 Convert a Single Lane Roundabout to a Dual Lane Roundabout

In general, a single lane roundabout is not likely to be a suitable candidate for roundabout signalisation. The reasons for considering the full signalisation of a roundabout as discussed in Section 6 are unlikely to be present at a single lane roundabout, with the exception of congestion / capacity issues, which would be most effectively treated with roundabout metering, or conversion to a dual lane roundabout. If the issues are safety related, speed control measures on the approach leg as discussed in Section 7.5.1 are likely to be more effective. While issues related to pedestrian or cyclist access would benefit from signalisation of the roundabout, unsignalised treatments should also be considered, such as a zebra crossing or raised wombat treatment. It should be noted that conversion from a single lane to dual lane roundabout is likely to lead to a poorer road safety outcome for pedestrians and cyclists. Hence if an existing single lane roundabout has both capacity issues and pedestrian and cyclist access or safety issues, then conversion to a dual lane signalised roundabout may be an appropriate treatment.

7.5.3 Free Flow Slip Bypass Lane

Free flow slip bypass lanes are an effective means of reducing the volume entering the roundabout at one or more approaches, and may be sufficient to improve capacity / congestion issues at an existing roundabout. Where left-turn slip lanes are to be provided pedestrian and cyclist needs should be taken into account (Austroads, 2020b), and require careful consideration. Where pedestrian and cyclists are expected to cross a slip lane, low vehicle speeds should be encouraged at the crossing point. Priority at crossings should be clear for all road users (i.e. whether motorists,

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transport/cycling/cycling-standards-and-guidance/cycling-network-guidance/designing-a-cycle-facility/intersections-and-crossings/roundabouts/signalised-roundabouts/)

pedestrians or cyclists have priority). An example free flow slip bypass lane layout is shown in Figure 7-3 below.

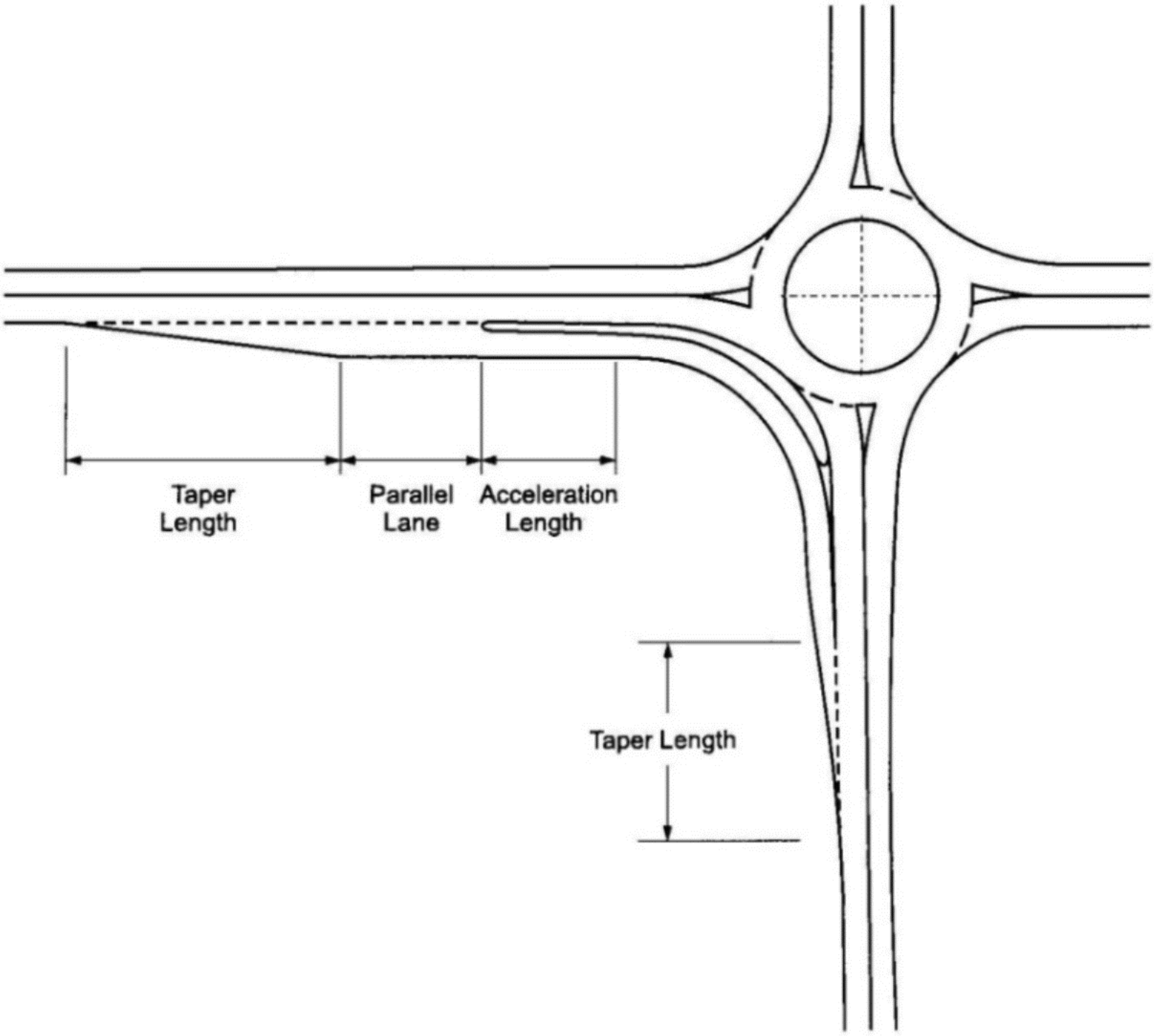


Figure 7-3: Left-Turn Free Flow Slip Lane, with Downstream Merge (source: Austroads, 2020b)

7.5.4 Roundabout Metering

Roundabout metering can be applied to help with unbalanced flow situations, and is generally most effective where congestion issues and queuing is prevalent on only one or two approach legs, caused by a dominant traffic stream on an upstream leg. Under roundabout metering, the dominant approach is metered to provide gaps for the downstream approach legs, often only activated during the peak periods. Roundabout metering may be a more cost effective treatment than signalisation, as it typically only requires signals to be installed on one approach leg of the roundabout, and generally doesn't require geometric modifications that are often required alongside full signalisation. Given both signalisation and roundabout metering can be applied to resolve capacity issues, traffic modelling of both options would be required to determine the most effective treatment.

A separate Main Roads document, Guidelines for the Analysis of Roundabout Metering Signals (Main Roads, 2015), provides guidance on the analysis of roundabout metering signals.

8 GEOMETRIC DESIGN CONSIDERATIONS

The requirements of Austroads Guide to Road Design - Part 4B - Roundabouts, and Main Roads Supplement to that guideline, are relevant to signalised roundabouts and should be applied to their geometric design. This section provides additional guidance for the unique features of signalised roundabouts relative to priority-controlled roundabouts.

8.1 Diameter and Internal Storage

A key criteria for a roundabout to be considered for full signalisation is its diameter. A sufficiently large diameter is required to provide adequate storage within the circulating lanes. Without adequate storage, queues would spill back into the upstream approach. In order to avoid queue spillback, cycle times would have to be very short and likely impractical. The risk of queue spillback could also be minimised by implementing a particular signal phasing that acknowledges one or more dominant turning movements.

Preliminary guidance on effective roundabout central island diameter is provided in Section 7.4. Ideally, standard 4 leg roundabouts should have a minimum diameter of 50 m for effective operation and storage for right turn movements. For oval shaped roundabouts, the smaller diameter will be critical, and hence the minimum dimension of 50 m at its narrowest dimension is required. Roundabouts with more than 4 legs will require larger diameters (i.e. desirably 80 m), and roundabouts with only 3 legs a smaller diameter of 40 m is likely to be adequate.

The minimum roundabout diameter limits the number of suitable candidate sites for roundabout signalisation. However recently roundabout design in WA has tended towards larger diameter roundabouts, often to cater for larger heavy vehicles, or at grade separated interchanges where spacing between the entry and exit ramps is relatively large to accommodate the grade-separated freeway / highway inbetween.

Smaller diameter roundabouts (less than 50 m central island diameter) are generally not considered suitable for full signalisation for the following reasons:

- Limited internal storage for stacking can result in blocking of the circulatory lanes, and lead to increased congestion and safety risk. For example, a 40 m diameter roundabout will typically have internal storage of approximately 12 to 18 m (depending on the geometry of the intersecting legs). The Right of Way vehicle in WA is the 19 m semi-trailer. With standard two-phase operation, only one right turning semi-trailer would be enough to block access for the through traffic. For roundabouts accommodating RAV access, the minimum internal storage requirement is higher.
- As the roundabout diameter is reduced, the spacing between traffic signals is reduced, and there is a higher risk of 'see-through' problems – i.e. drivers being able to see-through to the next set of traffic signals, and therefore reacting to the wrong signal.
- While traffic phasing can be designed to largely limit stacking in the internal storage areas, it cannot be completely eliminated, e.g. U-turning vehicles and very slow moving traffic that doesn't clear the roundabout within the expected phase times.

Full signalisation of smaller diameter roundabouts (less than 50 m central island diameter) may be achievable using alternative phasing techniques as discussed in Section 11.

8.2 Lane Configuration

Signalised roundabouts under full-time control offer the advantage of allowing three or more circulatory lanes, which will provide greater internal storage capacity and throughput. Under part time-control, the design must allow for operation of the roundabout under normal priority-control conditions, and generally the provision of three circulatory lanes is discouraged as it can become overly complex for drivers.

Traffic flow patterns should be investigated to develop potential lane configuration plans to cater for the design demand. As discussed in Section 7.3, a rule of thumb that can be applied to initial lane configuration is the sum of the external approach lane and internal approach lane at each roundabout node should be less than 1,500 pcu/h, or approximately 1,350 vph assuming 10% heavy vehicle composition. The lane configuration should identify:

- Opportunities for free-flow slip lanes, where left turn demands are high.
- Requirements for additional circulatory lanes.
- Opportunities for additional lanes on the external approaches, e.g. left-only lanes, that will only require local widening for the left turn movement, and not require additional circulatory lanes.
- Optimal location for widening of the external approaches to minimise the impact on the internal queue storage, i.e. widening on the inside or outside lane will impact downstream or upstream queue storage respectively. Figure 8-1 shows an example of widening the external approach on the outside lane.
- Opportunities to realign an external approach lane to increase the width of the splitter island, and thereby increase the internal queue storage.

Under part-time signal control, the scope for geometric modifications is reduced due to the requirements for the roundabout design to accommodate priority control access, i.e. to be in accordance with of Austroads Guide to Road Design - Part 4B - Roundabouts, and Main Roads Supplement to that guideline.

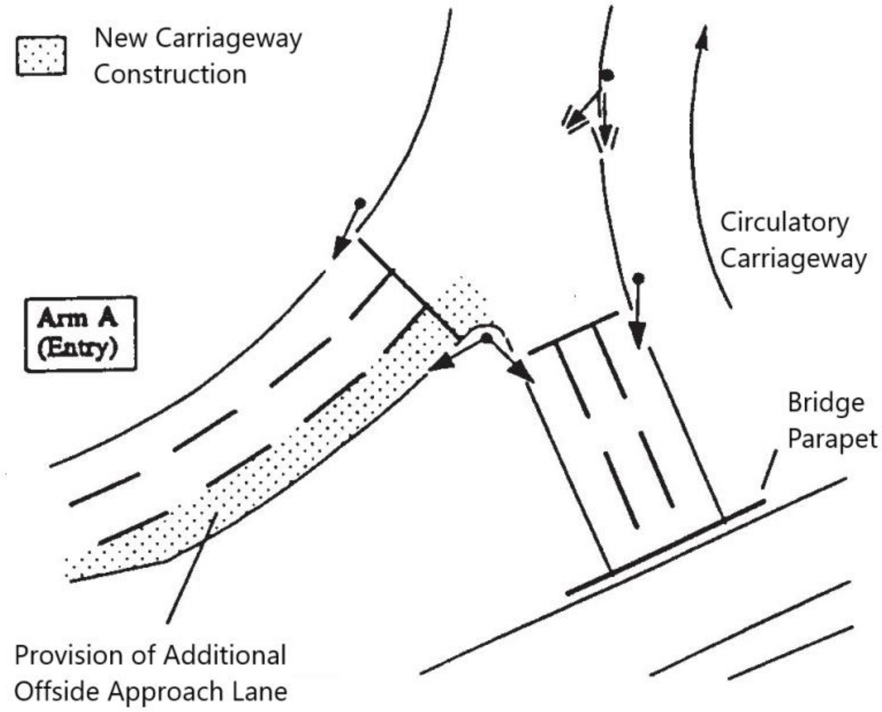


Figure 8-1: Provision of Additional Approach Lane to Improve Queue Storage and Discharge (source: DMRB, CD 116, National Highways, 2023)

8.3 Intersection Intervisibility Zone

Intersection intervisibility refers to the visibility of the intersection area and approaches to the intersection from both internal and external approach legs; i.e. circulating traffic on the internal approach should be able to see the intersection area and external approach lanes, and likewise traffic on the external approach lanes should be able to see the intersection area and internal approach lanes. Figure 8-2 shows the minimum intervisibility zone (the zone that should be visible for traffic in any approach lane).

The following guidance, adapted from DMRB, CD 116, (National Highways, 2023) should be followed:

- All internal and external approaches on roundabouts which operate under signal control at anytime shall be provided with an intervisibility zone which extends across the full carriageway width of each arm from a distance of 2.5 metres back from each stop line.
- For signal-controlled roundabouts the junction intervisibility zone on the circulatory carriageway should be measured to a point 2.5 metres beyond the secondary signal, as illustrated on Figure 8-2.
- Where an advance stop line (ASL) is provided on a roundabout approach, the intervisibility zone shall be measured from a point 2.5 metres behind the cycle stop line.
  Note: The intervisibility zone is measured from a point 2.5 metres behind the cyclists' stop line because the cycle reservoir behind the ASL does not create any physical impediment to intervisibility.
- Where there is a pedestrian crossing adjacent to a stop line, the intersection intervisibility should be extended to ensure that drivers of all vehicles on each entry lane are able to see the full extent of the pedestrian crossing (and its approach).
- The intersection intervisibility at a pedestrian crossing should include the full width of the strip of tactile paving laid parallel to the edge of carriageway.
- No substantial fixed obstructions shall be located within the intervisibility zone of new roundabouts.
- No substantial fixed obstructions should be located within the intervisibility zone of existing roundabouts.

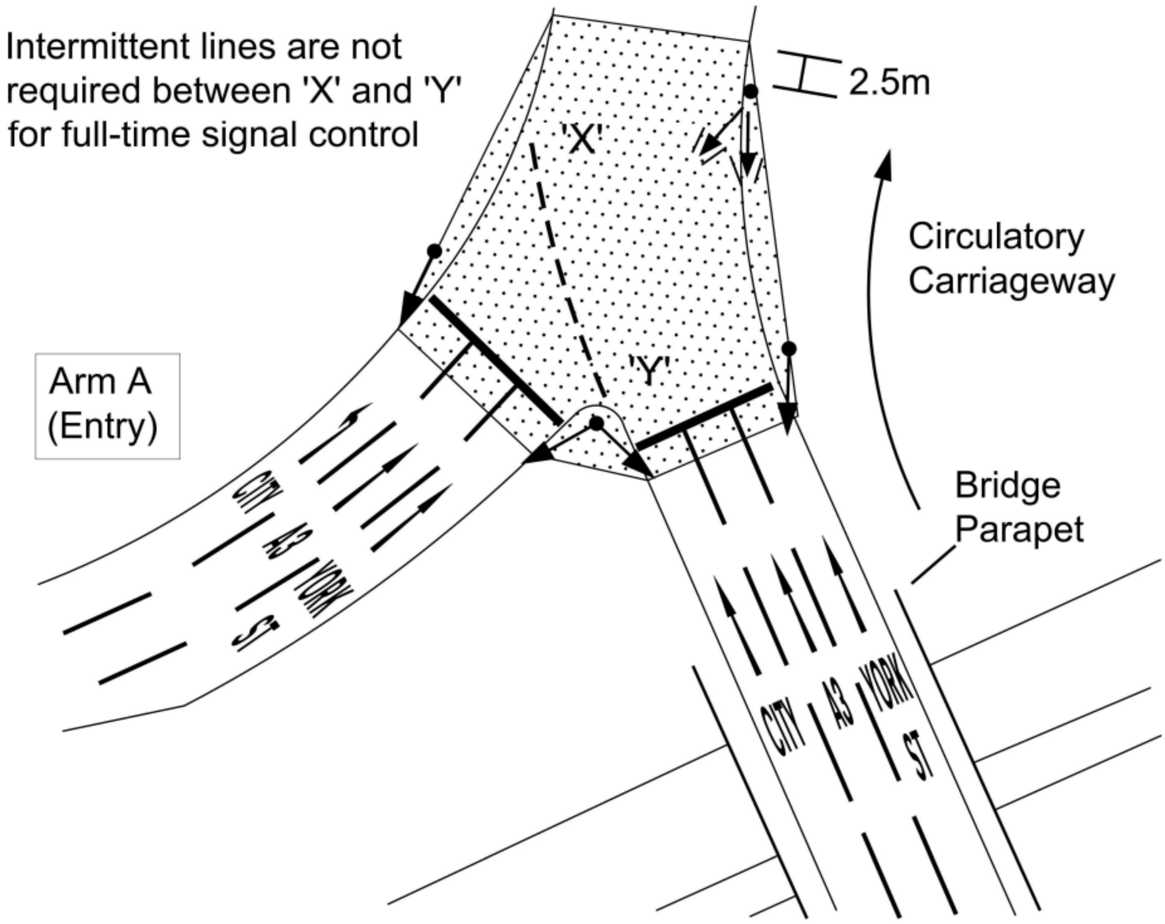


Figure 8-2: Intersection Intervisibility Zone on a Signal-Controlled Roundabout (source: DMR,B CD 116, National Highways, 2023)

8.4 Pedestrian and Cyclist Facilities

Full signalisation of roundabouts allows for signalised pedestrian / cyclist crossings at all external and internal approach legs. Combined with pedestrian crossings through the centre of the roundabout, this can provide access to all quadrants / nodes of the intersection. Departure legs can also be provided with signalised pedestrian and cyclist crossings through the introduce a separate phase at the upstream signals, where both internal and external approach legs are stopped. An example of this is shown in Figure 8-3 below. At this location the pedestrian / cyclist phase is activated by a pedestrian call button on the departure leg. The advantage of this layout is the crossing can be located very close to roundabout, i.e. storage on the departure leg prior to the pedestrian crossing is not required.

Figure 8-3: Example of Cyclist Crossing on Departure Leg, Princes Highway / East West Link / New Lake Entrance Road Roundabout, Oak Flats, NSW (Source: Google Maps)

Signalised crossings of the departure legs is not always required, provided that pedestrian crossings through the centre of the roundabout are installed. In some cases these can provide better sight distance for vehicles, and for some pedestrian movements provide more direct access, particularly diagonal crossings (i.e. trips turning right through the intersection). They can have particular advantage at grade-separated roundabout interchanges, where the piers and abutments for the flyover can create challenges for sight distance to pedestrian crossings at the departure legs. An indicative example of how pedestrian crossings could be installed only at the external and internal approach legs, whilst still achieving full access to all quadrants of the intersection, is shown in Figure 8-4.

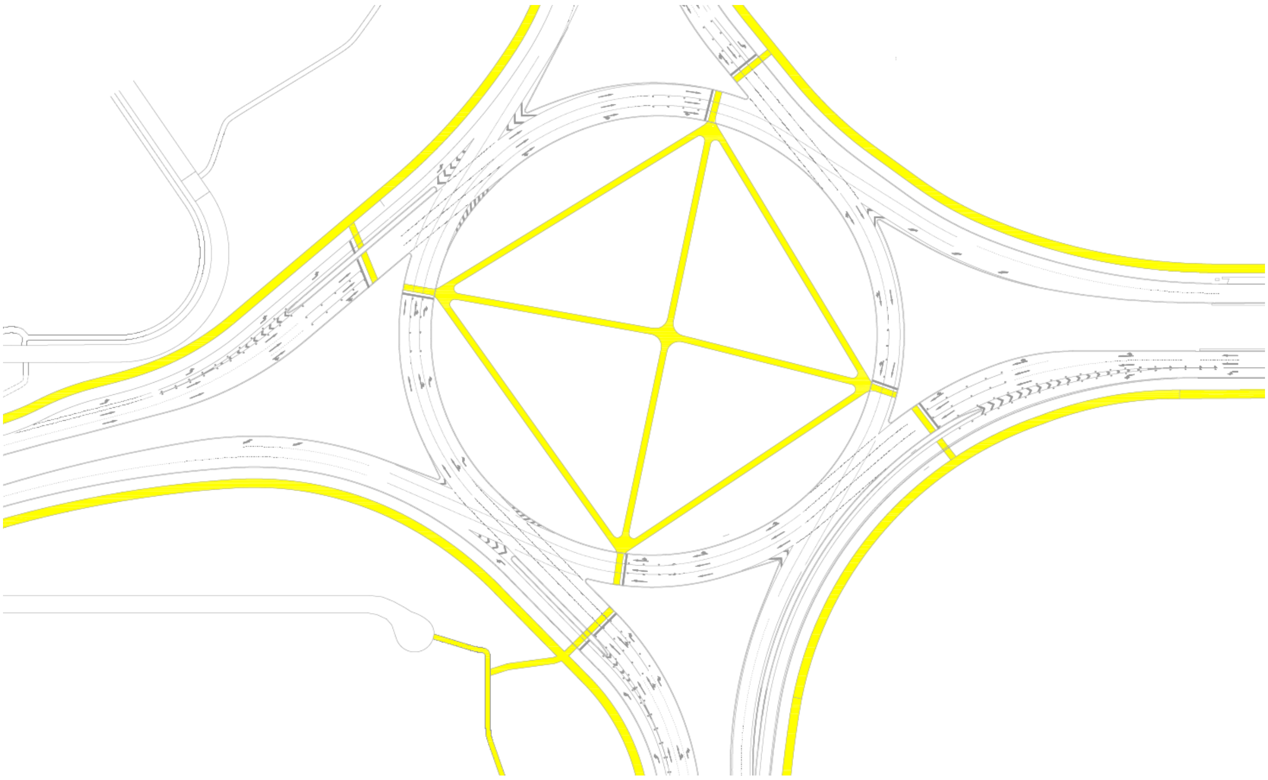


Figure 8-4: Indicative Example of Pedestrian Crossings on External and Internal Approach Legs to Provide Full Access

An alternative option is to provide a separate zebra or wombat pedestrian / cyclist crossing facilities on the departure legs. If the crossing is signalised or a zebra crossing, adequate storage length should be provided to avoid traffic queuing back onto the circulatory carriageway (DMRB, CD 116, National Highways, 2023). The minimum distance should be established through traffic modelling, and consideration of lane utilisation, and the time required for queue discharge.

Figure 8-5 below (extract from Austroads, 2017b) provides the distance required between the exit from the roundabout and a pedestrian crossing, based on typical carriageway widths (5 m for a single lane exit and 10 m for a two lane exit). This figure is based on an unsignalised crossing (zebra or wombat crossing), assuming low pedestrian flow, an average walking speed of 1.5 m/s, random vehicle arrival and, for two lanes, vehicles being queued in both lanes. If there is likely to be considerable pedestrian demands, signalised crossings on the departure legs may be required. Queue lengths will be longer under signalised control, as typically walking speeds of 1.2 m/s (or lower) are adopted, and allowances for Invitation-to-Cross period (6 seconds in WA) and clearance times are required. Reference should be made to the Guidelines for Pedestrian Crossing Facilities at Traffic Control Signals (Main Roads, 2023b).

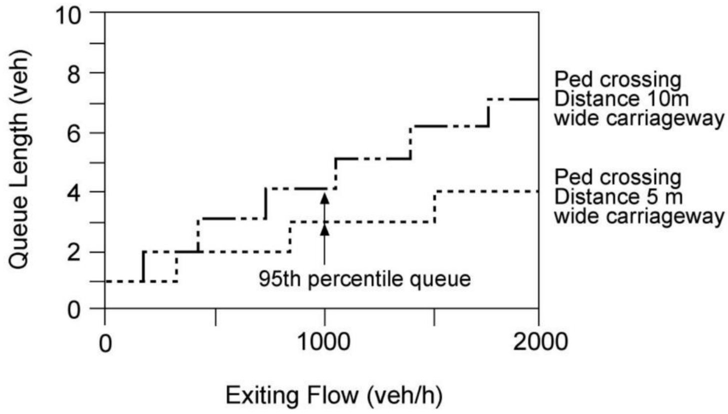


Figure 8-5: 95th Percentile Queue Length for Vehicles Waiting at Unsignalised Pedestrian Crossings (Austroads, 2017b)

For cyclists at roundabouts, in line with priority controlled roundabouts, an option to leave the road and use an off-road shared path is preferable, particularly for inexperienced cyclists and children (although commuter or experienced cyclists would generally prefer to use the roadway and ride through a roundabout with the traffic). There is some evidence to suggest that this is the safest design, at least when traffic flows are high (Austroads, 2020b).

In an area with significant bicycle usage (particularly children or recreational cyclists), facilities such as cyclist advance stop lines should be considered, which would further enhance their visibility on the road, and advanced green lights for cyclists (refer Section 9.2) to give cyclists a head-start entering the intersection.

Depending on physical and/or budget constraints as well as demands, a grade separated pedestrian/cyclist crossing could also be considered on one or multiple crossings of the roundabout system, either as a flyover or underpass.

Other specific guidance on designing roundabouts for pedestrians and cyclists is provided in Towards a Safe System Approach - Selection of Intersection Control Guidelines (Main Roads, 2025).

A summary of the key considerations of two main control options for pedestrian and cyclists is provided in Table 8-1 below.

Factor	Pedestrian Crossings at External and Internal Approach Legs (with internal access through roundabout)	Signalised Pedestrian Crossings at External Approach and Departure Legs (no access through the roundabout)
Access	More direct where the major pedestrian / cyclist routes need to cross two legs of the roundabout (i.e. routes turning right).	More direct for routes where the major pedestrian / cyclist routes only need to cross one leg of the roundabout (i.e. through routes).
Safety	Greater number of crossings required for pedestrian and cyclist through routes – higher exposure. Pedestrians and cyclists Vehicles likely to have better sight distance and awareness of pedestrian crossings.	Fewer crossings required for pedestrian and cyclist through routes – reduced exposure. Vehicles may have slightly less visibility and awareness of the pedestrian crossings on the departure legs, and are typically accelerating leaving the roundabout (however given crossings are signalised, the risk is very low).
Legibility	Relatively poor legibility, particularly when only crossing one leg.	Relatively conventional, with good legibility.
Traffic Efficiency	Pedestrian crossing phasing is incorporated into vehicle phasing, with minimal impact on traffic capacity and efficiency.	Additional signal phase required for the pedestrian / cyclist crossing, which may impact the efficiency and capacity of the roundabout for vehicular traffic.
Potential Suitable Locations	Grade-separated interchanges, where one or more of the shared path routes is also grade separated. Dumbbell roundabouts and very large diameter roundabouts, where the intersection size (between the internal leg stop line and the departure leg) is large.	At-grade roundabouts with shared paths or cycle routes along one or both of the intersecting roads.

Table 8-1: Pedestrian and Cyclist Crossing Options – Key Considerations

8.5 Heavy Vehicle Considerations

The design of a signal-controlled roundabout should consider the routing and associated lane choice of heavy vehicles through the roundabout, and must allow for the swept turning paths of the design vehicle for the associated route, considering entry, circulatory and exit lanes. Where two adjacent lanes cater for the same turning movement, Main Roads practice is to allow for the design vehicle in the left lane, and either a car or a single unit truck / bus in the right lane. Main Roads Supplement to Austroads Guide to Road Design Part 4 – Intersections and Crossing (Main Roads, 2023a) presents a graphical method to determine the vehicle combination required, based on the turning volume and proportion of heavy vehicles turning. Where the roundabout is on a heavy vehicle route, and the percentage of heavy vehicles in each lane is known (e.g. due to a right turn downstream of the roundabout with a strong heavy vehicle demand), there may be a need to allow for the design vehicle in both lanes.

An example of a signalised roundabout with adjacent lanes catering for the same turning movement is Eelup Roundabout in WA. Figure 8-3 below shows vehicle routing for each lane to and from the north, south and east legs (RAV 7 routes) and the west leg (a RAV 4 route). As shown, where two adjacent lanes cater for the same turning movement, the design vehicle (RAV 7 or RAV 4) should be adopted for the left lane, and a car or single unit truck in the right lane.

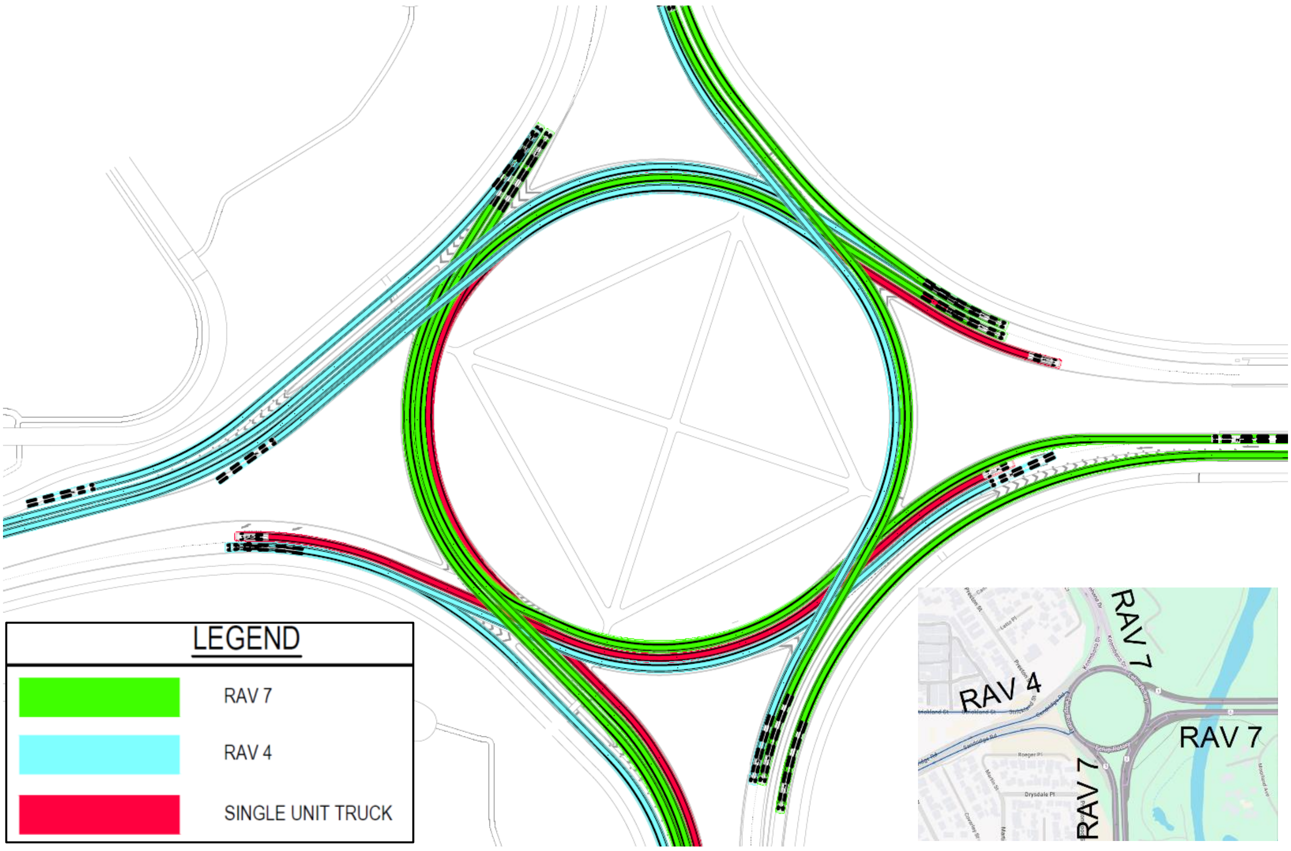


Figure 8-6: Example of Heavy Vehicle Routing and Appropriate Design Vehicle for each Lane (Eelup Rotary, Bunbury)

In some cases signalisation may result in traffic routing and lane allocation through the roundabout requiring heavy vehicles to use all circulatory lanes. This may result in wider carriageway widths than priority-controlled roundabouts. This is normally discouraged as it can result in higher circulating speeds, and reduce the entry path radii (i.e. result in a higher angle of conflict).

Heavy vehicle speeds need to be controlled through roundabouts, particularly where approach speeds are high, to ensure the stability of trucks with a High Centre of Gravity is maintained. The assessment should be undertaken using simulation software in accordance with the Guidelines for Vehicle Stability Analysis – Main Roads Internal Process (Main Roads, 2019).

8.6 Signage and Pavement Marking

Signage and pavement marking form an integral part of improving wayfinding as well as safety. This is particularly important on complex multi-lane roundabouts, which can be confusing or disorienting for unfamilar motorists if signage and road markings are not implemented appropriately.

Give-way hold lines at the roundabout must be replaced with stop lines. Stop lines should be perpendicular to the carriageway to allow better visibility of the traffic signal lanterns from all lanes. Stop line set back should allow for pedestrian crossings as discussed in Section 8.4.

Initially, drivers may require higher level of warning and advice so they do not mistake the treatment for a conventional roundabout (Austroads, 2015).

At larger roundabouts, where space permits, advanced destination signage and pavement marking should be considered to improve approach legibility and minimise lane-changing within the roundabout. An example of this application at Eelup Rotary is shown in Figure 8-7 below.

Minor warning signage at signalised roundabouts is based on those typically applied at signals, rather than priority controlled roundabouts. For example, at the external approach legs, W3-3 signs (Signals Ahead) should be installed, rather than W2-7 signs (Roundabout Ahead). R1-3 signs (Roundabout Give Way) are not installed at the signalised external approach legs. Refer to Appendix C for an example LMB (Signage and Pavement Marking) drawing at Eelup Rotary in Bunbury.

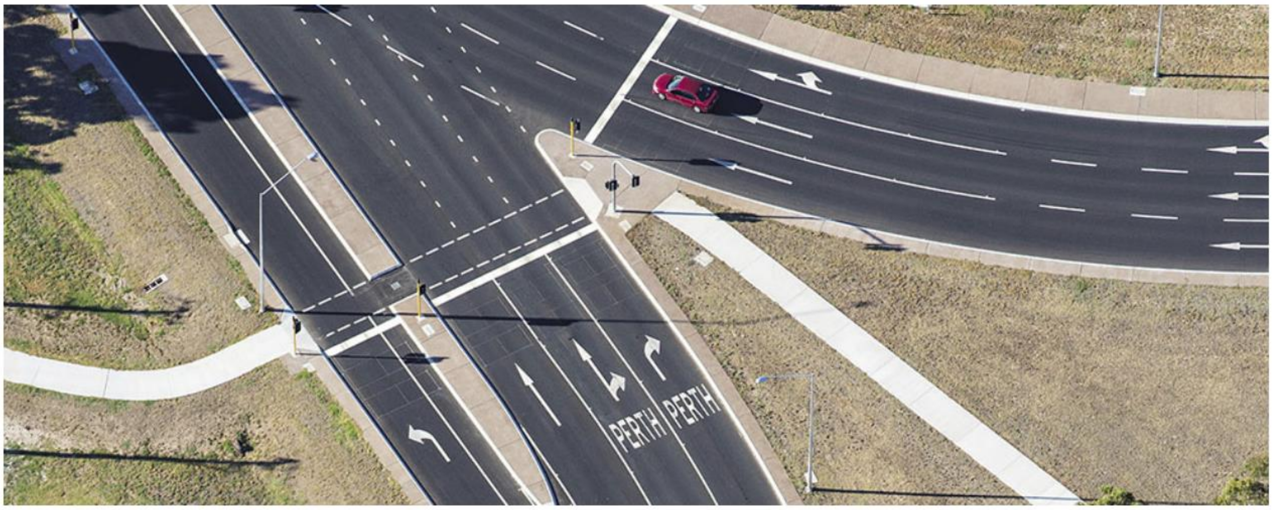


Figure 8-7: Advanced Destination Pavement Marking (Eelup Rotary, Bunbury)

Yellow box markings may be beneficial to signalised roundabouts with limited storage areas, however is typically only applied at existing signalised intersections where there is evidence of queue spillback through the intersection impeding traffic flow or pedestrian and cyclist access through the intersection. This pavement marking should be applied in accordance with the Policy and Application Guidelines: Yellow Box Markings at Signalised Intersections (Main Roads, 2021).

The UK's Local Transport Note 1/09 - Signal Controlled Roundabouts (Department for Transport, 2009), as well as DMRB, CD 116, (National Highways, 2023) provide the following general guidance in relation to pavement marking at signalised roundabouts. This is provided below for reference, however application of signage and linemarking should be in accordance with Main Roads and Australian Standards requirements, and Main Roads and Australian Standards should always take precedence. Western Australian specific guidance is provided in italics in the list below where it significantly differs from UK guidance.

- Road markings
    - At roundabouts with full-time signals, there should be a stop line that should be straight and at right angles to the carriageway, and no markings at the entrance to the roundabout whatsoever. *In Western Australia, special guide lines may be applied to provide guidance to the appropriate circulating lane.*
    - At roundabouts with part-time signals, the standard roundabout 'give way' markings should be provided in addition to the signal stop line.
    - For unsignalised nodes, the standard roundabout 'give way' markings would otherwise apply.
    - For signalised roundabouts, the choice of markings depends greatly on the traffic flow distribution and the queuing space required on the circulating carriageway, but spiral markings should be the first choice. This will make navigating the roundabout clear for drivers and minimise weaving and lane changing.

- Spiral markings
    - These are lane markings around a roundabout that indicate a route through the roundabout with minimal need for lane changing, and should be the prime choice for markings at a signalised roundabout. Destination markings and signs are essential to this approach, and should be as clear and abbreviated as possible in order to minimise information overload.
    - Arrows may be provided on each lane to indicate the traffic movements intended to use it. They should be placed at the beginning of the lane (where they are least likely to be hidden by stationary traffic) and repeated further up the lane for sections that are longer or more heavily used. The destination, expressed as the road number or town name, can also be added where necessary. This might not be appropriate at smaller roundabouts where carriageway area is limited.
    - Right turning arrows on entry lanes are 'best avoided': this is particularly true where there is a danger that they might be interpreted as permitting a right turn on to the circulating carriageway. *In Western Australia, right turn arrows are often installed at external approach legs to designate the appropriate late for right turning vehicles.*
    - Safety of cycles and particularly motorcycles must be considered when designing a road marking scheme. Raised road markings can cause problems either by affecting their stability or by retaining water on the surface, resulting in a loss of adhesion between the tyres and the road. High friction road marking materials should be used, especially on curved sections and, where speeds are high, to reduce skidding when surfaces are wet.

- Hatchings and chevrons

    - Hatching can be useful when adjusting lane markings where an existing roundabout is being converted to signalised operation or spiral markings are introduced.
    - Chevron markings may be used to create ghost islands where lanes need to be separated (e.g. on free, segregated left turns or to help define desire lines).

- Guidance markings
    - Guidance markings can be used to indicate vehicle paths where lanes cross or merge.
    - There is a safety issue with the design of guidance markings. Having guidance markings immediately after a stop line or 'give way' markings has been shown to significantly increase the number of overshoots. Therefore for signalised roundabouts there is usually a 10-15 m gap before the markings start.

- Signing
    - The best form of advance direction signing to the roundabout system approaches is a diagrammatic type sign that indicates destinations and also identifies the junction as being a roundabout.
    - Lane destination signs using direction arrows, route numbers or destinations can be particularly effective as a supplement to markings on the approaches to a roundabout, as well as all circulating lanes. Where traffic signs are used, lane and route identification on the signs should be consistent with the lane markings.
    - Main Roads Hazard Marker signs should be installed as per priority controlled roundabout requirements, e.g. MR-HM-1 and MR-HM-3 signs to show direction of travel at the entry points to the roundabout.

Specific guidance for spiral lane marking is provided in Towards a Safe System Approach - Selection of Intersection Control Guidelines (Main Roads, 2025).

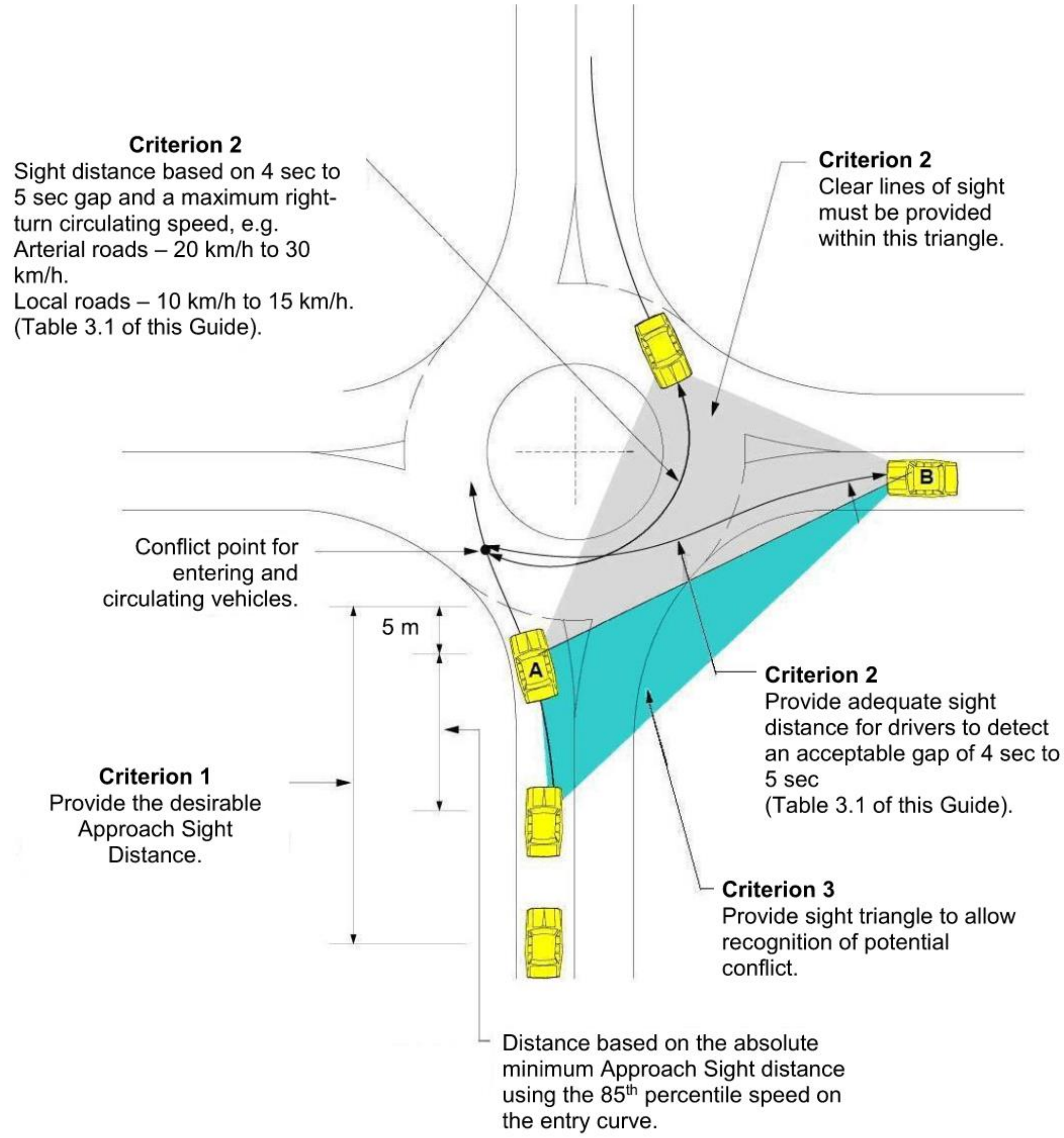
An example Signage and Pavement Marking (LMB) drawing is provided in Appendix C. This shows the LMB for Eelup Rotary in Western Australia, which shows typical type, positioning and layout of minor signage and pavement parking.

8.7 Traffic Signal Displays

Signalised roundabouts may have multilane approaches both on the entries and the circulating carriageway. It is essential that signal displays are visible to all road users to whom they apply (Austroads, 2023a). Green signals will normally be in the form of a full green aspect rather than a green arrow. Using green arrows where they are not required can cause problems (Department for Transport, 2009).

Approaching vehicles should be able to sight the traffic signal display from a minimum distance equivalent to Criterion 1 (ASD), as shown in Figure 8-8 below. Sight distance Criteria 2 and 3 are desirable in the event the signal fails and the intersection reverts to operation as an unsignalised roundabout. ASD should also be achieved on the traffic signal displays on internal legs.

A potential safety concern to be mindful of is the traffic signal 'see-through effect' where there is potential visibility of traffic signal displays on the internal approach legs of the roundabouts from the upstream intersection nodes. Visibility of these displays should be minimised from those at the upstream nodes to reduce the likelihood of driver error resulting in collisions. Such effects can be mitigated through the use of louvres or angling the displays to ensure that the visibility is limited to only the traffic to which they apply.



Note: Values for approach sight distance are provided in Table 3.1 of AGRD Part 4A.

Source: Adapted from Department of Main Roads (2006).

Figure 8-8: Roundabout Sight Distance Requirements – Austroads Guide to Road Design Part 4b - Roundabouts

8.8 Lighting Requirements

All signalised roundabouts require compliant lighting in accordance with AS/NZS1158.1.1 and AS/NZS1158.4 standards and the Lighting Design Guideline for Roadway and Public Spaces (Main Roads, 2024b).

8.9 Oval Roundabout Considerations

Oval roundabouts are often installed at grade-separated interchanges, to cater for the greater separation required between entry and exit ramps either side of the Freeway. This can result in disproportionate internal storage on the short internal legs compared to the long internal legs. Three phase signal operation may be required to cater for the exit ramp movements (primarily right and left turn movements) and clear the right turn demand. Refer to Section 9.2 for signal phasing options.

An example of a signalised oval roundabout is shown in Figure 8-9 below. This is also an example of a partial control roundabout (refer Section 9.3), whereby the longer internal storage over the A14 (the free-flow motorway below) allows the entry from the minor road (Cambridge Road) to enter under priority control.

Figure 8-9: Example Signalised Oval Roundabout – A10 / A14 / Milton Road Interchange, Milton, Cambridge, UK (source: Google Maps)

8.10 Three Leg Roundabout Considerations

With three leg roundabouts, smaller diameters may be acceptable, depending on the approach leg geometry and available internal storage. Signal phasing is likely to be further simplified, and therefore shorter cycle times may be possible. Refer to Section 9.2 for signal phasing options.

8.11 Dumbbell Roundabout Considerations

Dumbbell roundabouts (sometimes referred to as "dog-bone" roundabouts in WA) are common at grade separated interchanges, as they allow for a smaller bridge footprint and structure size across the freeway or highway between the roundabout terminals, which are installed on each side of the freeway or highway. This results in long internal legs in one direction, perpendicular to the freeway. However the diameter of the roundabout terminals are relatively small, typically ranging from 20 to 40 m at existing dumbbell roundabouts in WA, resulting in very limited storage on the internal legs parallel to the freeway.

Signalisation of dumbbell roundabouts can still be achieved as shown in the example in Figure 8-10 below, by only signalising the long internal legs perpendicular to the freeway. This requires dedicated storage lanes for the right turn movements from the arterial road to the freeway entry ramps, as well as additional signal phases to cater for this demand. Longer inter-green times may also be required compared to normal signalised intersections to account for the geometry, assuming limited or no storage space is available on the short internal leg of the roundabout, and to ensure right turn traffic from the arterial road has adequate time to clear the intersection node. Late start (for vehicle movements) or delay (for pedestrian movements) can be applied to the relevant minor movements for the purpose of clearing their conflict area. Refer to Section 9.2 for signal phasing options.

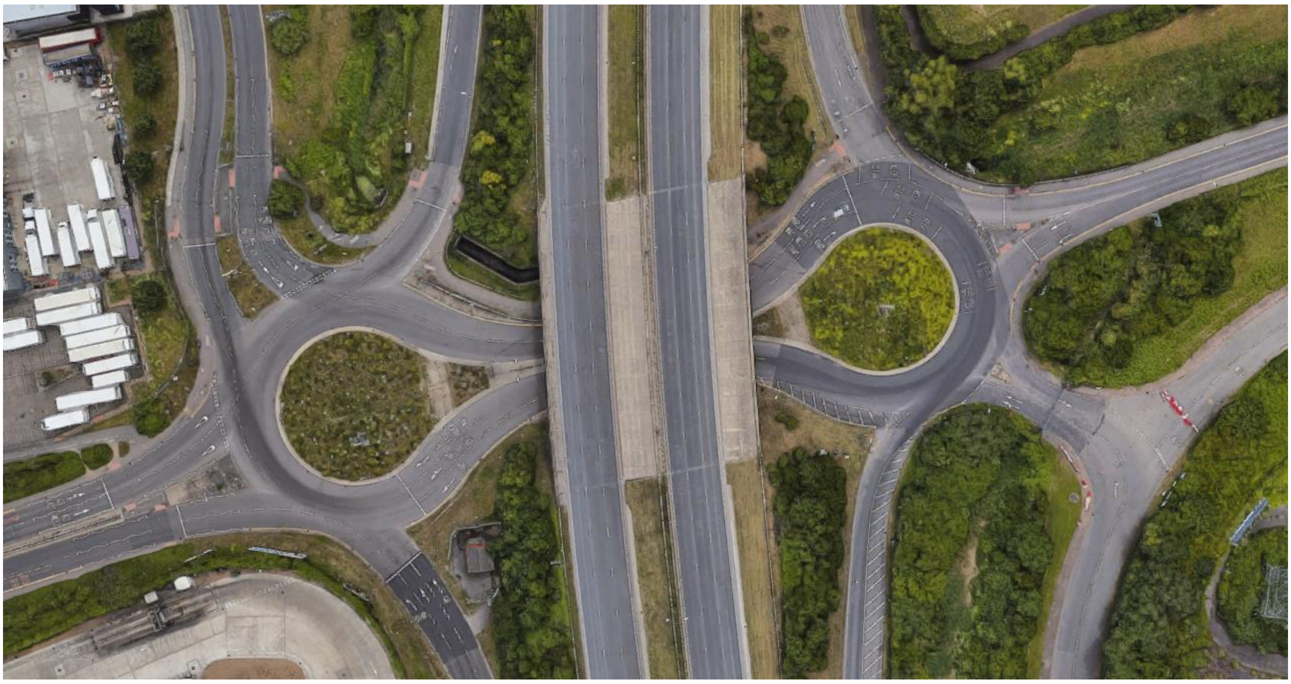


Figure 8-10: Example Signalised Dumbbell Roundabout – A13 / Marsh Way / Consul Ave, Rainham, UK (source: Google Maps)

8.12 Smaller Diameter Roundabouts with Cut Through Right Turns

Also referred to as a 'Tennis Ball' interchange, this is a variation of a dumbbell interchange, however allows right turn movements to 'cut-through' the roundabout central islands, which may be needed to minimise the intersection footprint or cater for larger design vehicles. While this layout is effective at reducing speeds through the interchange, it is not as effective at reducing right-angle conflict risk, compared to a well-designed roundabout or dumbbell roundabout layout.

An example of this is the Roe Highway / Berkshire Road interchange in Forrestfield, W.A., as shown in Figure 8-11. Three or more signal phases are required to cater for the right turn movements, usually using diamond overlap phasing. Refer to Section 9.2 for signal phasing options.

Figure 8-11: Example Signalised 'Tennis-Ball' Interchange – Roe Highway / Berkshire Road, Forrestfield, WA

9 OPERATIONAL CONSIDERATIONS

9.1 Cycle Time Considerations

Traffic modelling (as discussed in Section 10) is required to optimise cycle time length in order to reduce queuing, particularly on the circulating carriageway. As per Austroads AGTM Part 6, shorter cycle times are preferred to minimise queuing and storage issues on the circulating carriageway. UK and NZ experience suggest cycle times of 40 to 70 seconds are common for two-phase operation. The signals at Eelup Rotary in Bunbury typically operate with a cycle time of 55 to 80 seconds when only two phases are needed (off-peak), and 90 seconds to 110s during peak periods when the third phase is called.

As a rule of thumb, an initial cycle time can be based on double the average travel time for each movement, i.e. the travel time from an external stop line to clear the roundabout, multiplied by two, which allows for queue clearance (Simmonite, H. 2008). While this initial cycle time can be used as a starting point, iterations of +/- 5 to 10 seconds should then be tested in the model to identify the optimal cycle time. Alternatively SIDRA or LinSig may be used to help identify an optimal cycle time. Where pedestrian crossings are present, cycle times may need to be higher to accommodate minimum crossing times, particularly where pedestrian crossings are present on the departure leg and an additional phase is required (refer Section 8.4).

Inter-green times (yellow plus red) should be calculated in accordance with Austroads Guide to Traffic Management Part 9: Transport Control Systems – Strategies and Operations (Austroads, 2020c). This should be based on the design speed of the circulatory carriageway.

9.2 Signal Phasing Options

Main Roads is currently developing the Guidelines for the Operational Phasing at Traffic Control Signals (Main Roads, TBA). These guidelines should be reference for general operational requirements of traffic signals. Additional guidance unique to signalised roundabouts is provided below, including potential phasing control options. The figures below show pedestrian phases in green, and assume paths are provided within the central island to provide connectivity across the roundabout.

Two-phase control is generally preferred to provide alternating green waves for east-west and north-south through traffic (Murat & Guo, 2021). A typical two-phase traffic movement diagram is shown in Figure 9-1 below. An early cut off can be applied to one of the through movements to facilitate the more dominant right turn movement and clear queues that have built up within the circulating carriageway.

It is clear that the number of right turning vehicles and associated storage requirements within the circulating carriageway have a big impact on the operational efficiency of the signalised roundabout.

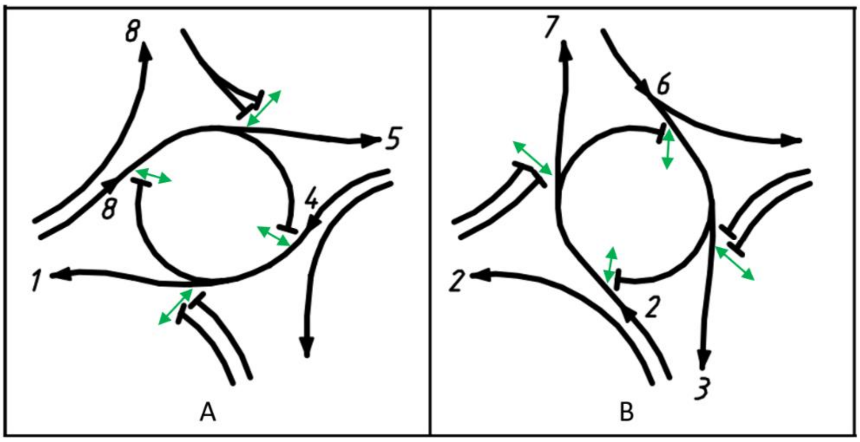


Figure 9-1: Traffic Movement Diagram – Typical Two-Phase Operation

Three phase control is often used at an intersection of secondary roads and main roads. It can also be applied at grade separated interchanges, to cater for the heavy right turn demand from the freeway or highway exit ramps. A typical three phase traffic movement diagram is shown in Figure 9-2 below.

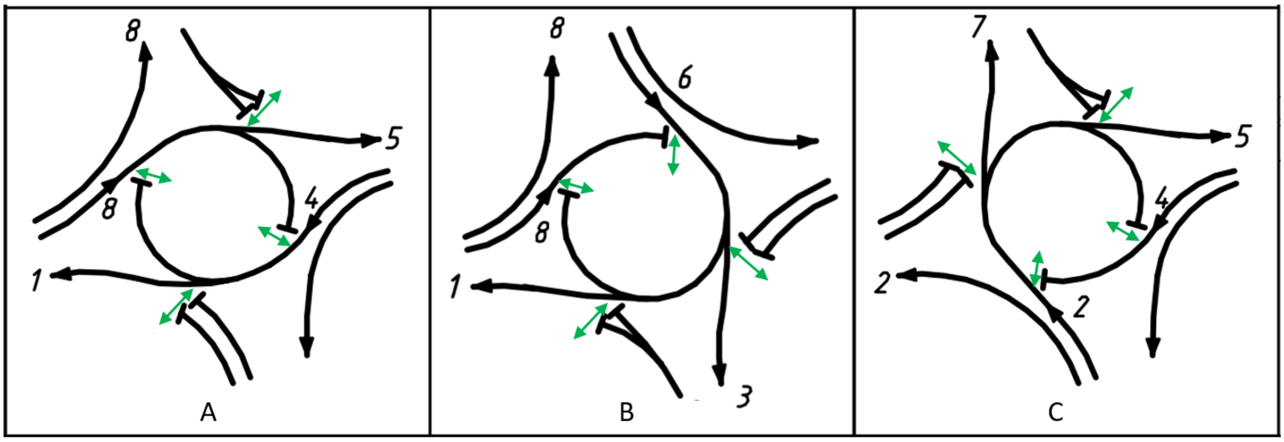


Figure 9-2: Traffic Movement Diagram – Typical Three-Phase Operation

Four phase control is typically provided for high right turn volumes, or where internal storage for right turn movements is limited. The additional phases may be variable phases, which may only operate in the peak periods for these movements, or to accommodate unusual traffic demand (special events or holiday demand). For example the signal phasing shown in Figure 9-3 below which provides Phase B for the right turn movement from the east, and Phase D for the heavy right turn from the south (adapted from the phasing for Eelup Rotary).

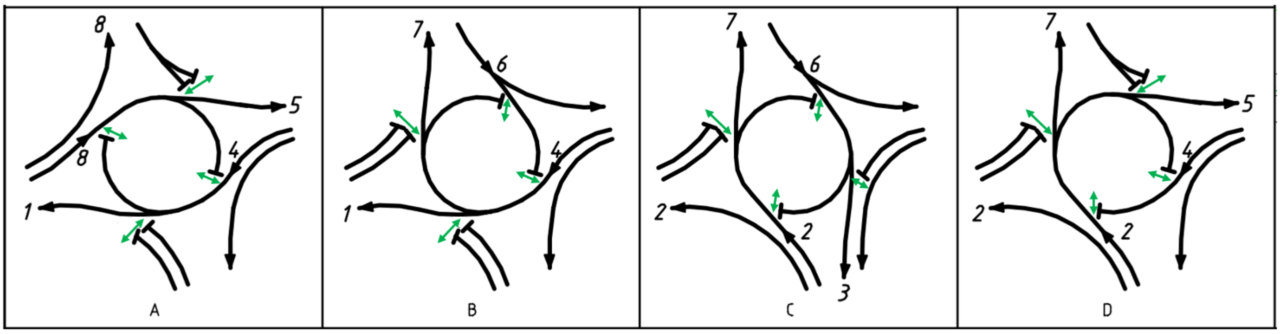


Figure 9-3: Traffic Movement Diagram – Four-Phase Operation for Heavy Right Turn Movements

For greater operational flexibility, the phasing plan shown in Figure 9-4 below allows alternate right turn clearance phases for either approach leg – Phase B1 and B2, and Phases D1 and D2. This may better suit the typical tidal patterns observed in morning and afternoon peak periods, e.g. Phase B1 may be called in the AM peak when westbound traffic is heaviest, and Phase B2 would be called in the PM peak when eastbound traffic is heaviest.

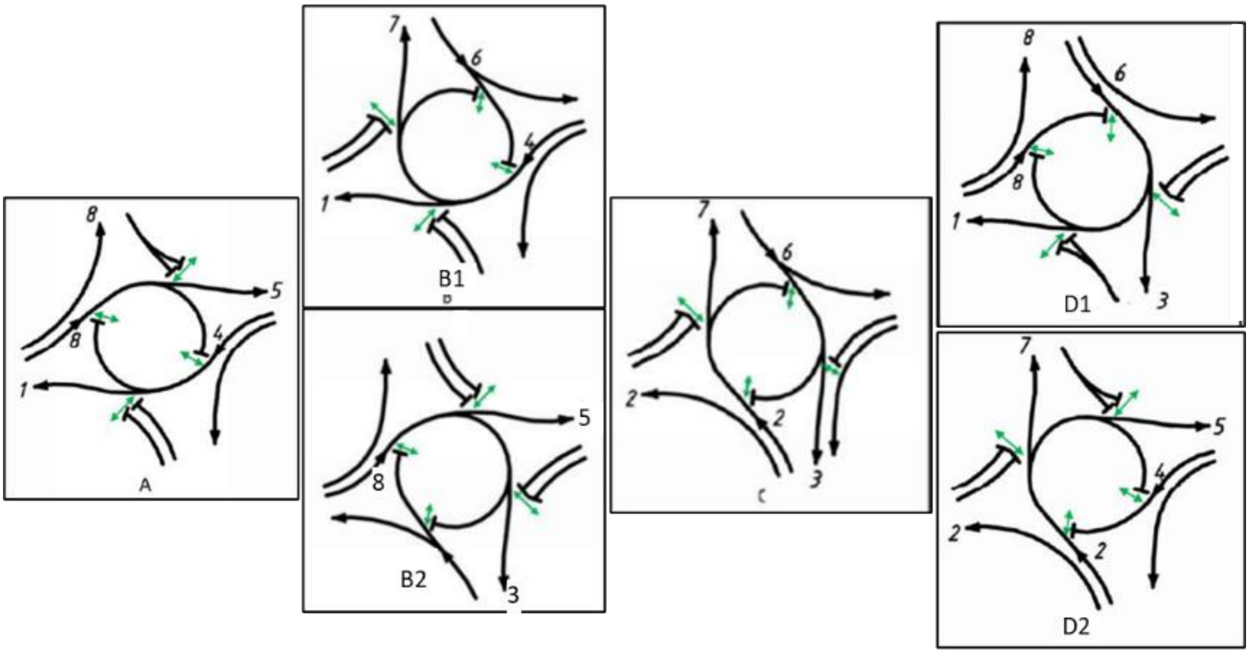


Figure 9-4: Traffic Movement Diagram – Four-Phase Operation with Alternate Right Turn Phase Options

Another option to consider is shown in Figure 9-5, whereby each node of the roundabout is operated as a separate intersection, with each intersection linked in SCATS. This phasing method is commonly applied in the UK. This setup maintains maximum flexibility, particularly during off-peak periods, in which the 'resting phase' is the circulatory phase, so that after the vehicle has entered the roundabout, it would not need to stop within the roundabout regardless of the exit. This setup provides greater flexibility to respond to the fluctuations in traffic volume and traffic movements which could vary throughout the day, however relies on careful consideration of the SCATS linking rules, and associated traffic modelling to ensure internal storage can adequately cater for demand.

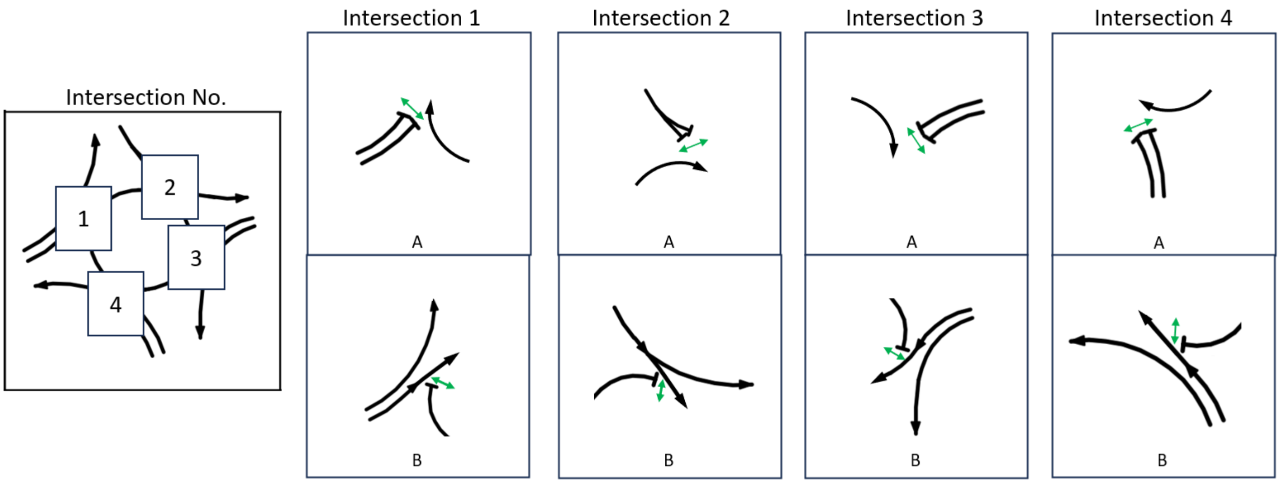


Figure 9-5: Traffic Movement Diagram – Separate Linked Intersections

The overall phasing sequence can be made up of a series and progression of through phases (north-south and east-west through movements, with right turn movements held on the internal legs) and 'split' phases (complete through and rights from dominant approaches), which is not dissimilar to single-node conventional signalised intersections. The objective for efficient operation is therefore to minimise the delay and queuing for all movements as much as possible, by minimising stopping frequency within the circulating lanes and allowing for a smooth flow around the system, particularly for dominant movements. Just like with any system, there may inevitably be delays, especially for the minor through or right turn movements that may be stopped several times along the series of nodes.

Professional judgement and appreciation of constraints will be required to know at what point the 'optimum' results can be reached – whether the system can be improved by adding in additional approach/circulating lanes (and on what nodes), or another free flow slip lane, or flaring the movements differently to achieve the desired lane utilisation, or modifying the cycle and phase times, or even rearranging the phase sequence. Physical attributes such as roundabout size, number of legs may even need to be finetuned. Careful consideration also needs to be taken to avoid unusual phasing makeup and sequence, as well as factors such as the risk of 'see-throughs' between subsequent roundabout nodes. In other words, there are no right and wrong solutions, and the numerous aforementioned levers will need to be controlled in order to achieve an efficient modelling process.

Signal phasing for a 'Tennis-Ball' interchange is shown in Figure 9-6 below (adapted from the signal phasing at Roe Highway / Berkshire Road interchange). This adopts three phase control typically adopted at a conventional diamond phasing. This is similar to that described for three-phase operation above, however in this case the right turn from the off ramp operates at the same time as the right turn from the arterial road, which is beneficial if right turn volumes from both legs are relatively high. Signal phasing for a dumbbell roundabout (where only the long internal legs are signalised, as shown in Figure 8-11) would generally operate under a similar phasing arrangement.

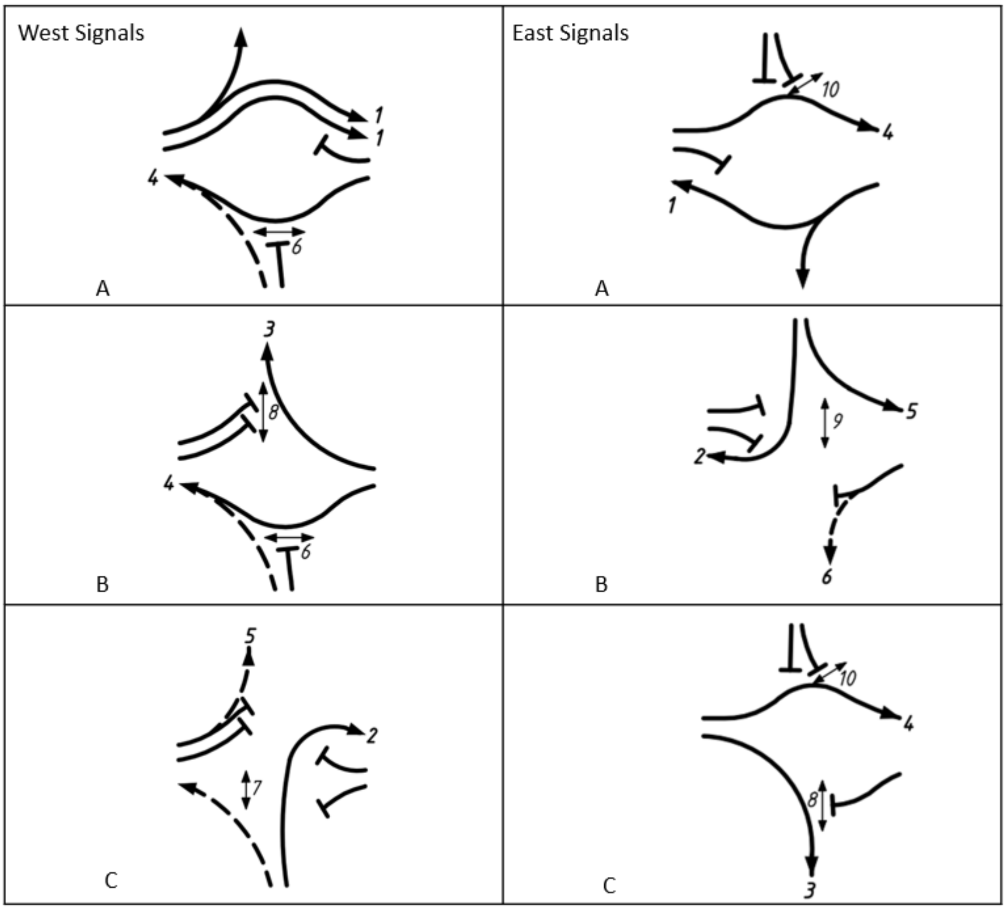


Figure 9-6: Traffic Movement Diagram – 'Tennis Ball' Interchange (from Roe Highway / Berkshire Road)

Advanced green lights for cyclists should be considered where cyclist volumes are significant. This is provided via dedicated bicycle signal lanterns (installed on the traffic signal pole at cyclist eye-height), along with bicycle detection loops within the cyclist advance stop line. These lights give cyclists a short (typically 4 to 6 seconds) head start on the vehicle green light, which gives cyclists adequate time to clear an intersection before conflicting movements receive a green signal, and reduce the risk of drivers not seeing a cyclist.

Consideration should also be given to alternative phasing requirements, for example to accommodate major traffic detours on the road network, or to accommodate specific freight or Over Size – Over Mass movements.

9.3 Full or Partial Control

Signalised roundabouts can be fully controlled, i.e. all nodes (including internal and external legs) are signalised, or partially controlled, i.e. one or more of the approaches remain under priority control. Partial signal control may be appropriate where traffic flows on the minor roads are light and continue to operate in a self-regulating manner under normal priority control (National Highways, 2023). There must be adequate storage at the stop-line in the circulatory carriageway downstream of the approach leg under partial control to cater for the forecast demand.

For the sake of clarity, a signalised roundabout with one or more free-flow slip bypass lanes for left turning vehicles is still considered a fully signalised roundabout.

Partial signalisation is particularly useful at smaller roundabouts since it requires less storage space for queuing within the roundabout.

Leaving one or more entries under priority control often provides better progression for all traffic through the roundabout. Often a roundabout that will not work with all the legs under signal control, will work if one or more legs are left under giveway control (Chard, Thomson and Bargh, 2009). This paper recommends the following criteria for legs that should be considered for give way control:

- The entry flow is low (i.e. below say 850 pcu/hr in both peak periods).
- There is sufficient stacking room for gap takers to store at the next stop line within the roundabout.
- There is a closely associated upstream signal controlled roundabout node to provide interstage gaps.
- Where, if you were not to leave an entry as give way, this would necessitate three traffic stages at one of the roundabout nodes to control.

Traffic assessment of selected legs with and without signalised control should be undertaken to evaluate the overall performance of the roundabout as fully or partially controlled, to determine the optimal configuration.

At roundabouts under partial signal control, vehicle counter loops must be installed on the priority controlled approaches. Providing detection at all approach legs assists with signal optimisation, and allows for more accurate traffic modelling, e.g. for ongoing performance evaluation (both safety and traffic efficiency), and for future road network planning.

9.4 Full-time or Part-time Signalisation

Full-time signalisation refers to traffic signals in operation 24 hours a day, 7 days a week, while part-time signals are in operation during only part of the day, typically during peak periods (e.g. commuter AM and PM peak hours) or when traffic demands on one or more legs reaches a threshold. The rest of the time the roundabout operates on a priority basis. Stop lines and signal poles must necessarily be set back approximately 20 m from the giveway line, similar to roundabout metering.

Main Roads preference is for a signalised roundabout to operate under full-time control, unless the roundabout operates under roundabout metering (indirect signal control), which normally only operates during peak periods.

Potential issues associated with part-time control include:

- Pavement marking for traffic signals requires stop hold lines at the signal posts. However priority controlled roundabouts operate most efficiently under give-way control, which allows traffic to enter the roundabout at speed, requiring much lower gap-acceptance. With part time signalisation, the stop line for traffic signal control would need to be set back approximately 20 m from the roundabout give-way line. This could lead to potential risks for unfamiliar drivers, such as stopping at the stop line when the signals are not in operation (potential risk of rear-end crashes), or stopping unnecessarily at the give-way hold line when signals are in operation (also potential risk of rear-end crashes).
- “The flares necessary for the operation of an uncontrolled roundabout are not appropriate for signal control, which requires a more rigid lane structure for optimum operation. Also

the entry deflections required by TD 16/07 Geometric Design of Roundabouts (HA, 2007) need to be retained for the non-signalled operating periods" (Department for Transport, 2009).

- With part-time signal operation, there are limited options to provide safe pedestrian crossing facilities for visually impaired pedestrians, as there is no effective way of indicating in a non-visual way that the signals are not operational. Consequently, signalised pedestrian facilities cannot be recommended for part-time signals (Department for Transport, 2009).
- As discussed in Section 8.5, part-time signalisation might not be appropriate for roundabouts where the design vehicle is greater than a 19.0 m semi-trailer, and lane allocation to suit signalisation results in the design vehicle being required to use all circulatory lanes. This is likely to result in wider circulatory carriageway widths, which can result in higher circulatory speeds and poor entry path radii, which are undesirable outcomes for a priority-controlled roundabout.
- As discussed in the Update to Guide to Road Design: Intersections (Austroads, 2023b), additional signage on operating times would be required in order to reduce confusion about the difference between metered and signalised roundabouts.
- The transition from signal control to operation under priority control could also lead to driver confusion (e.g. drivers holding at the signals after they have been turned-off, with potential risk of rear end crashes).

9.5 Traffic Control System and ITS Requirements

As outlined in Local Transport Note 1/09 - Signal Controlled Roundabouts (Department for Transport, 2009), roundabout signals can be co-ordinated with surrounding signals where advantageous, however cycle times for roundabouts may be less than normal for the surrounding network, which may limit the potential linking opportunities. Austroads AGTM Part 6 notes that signalised roundabouts may require different forms of traffic control than standard signalised intersections (e.g. SCATS Masterlink mode may not be compatible, requiring a roundabout to be operated in Flexilink, isolated mode). Master-Isolated mode may also be an option, which allows the signal to operate in isolation, however allows more advanced SCATS settings to be applied. For further guidance on traffic signal control settings, refer to Part 9 of the Guide to Traffic Management (Austroads 2020c), and the Guidelines for 'Operational Phasing at Traffic Control Signals' (Main Roads, TBA)".

Generally a single Traffic Signal Controller (TSC) should be adequate to operate all four signalised nodes. For very large roundabouts, more than one TSC may be considered. The advantages of a single TSC include:

- Simpler phasing set up.
- Lower cost.

Considerations for operating with more than one TSC include:

- Distance between the TSC and detector loops can be reduced. Detector loops should typically be located within 100 m of a TSC (although longer distances are achievable).
- More complex signal coordination, typically requiring a master-slave system. Whilst this adds complexity, it allows separate time settings, phase and cycle times for movements at each TSC, which may provide benefit to operation.

Main Roads Electrical Asset Management should be consulted during the concept design stage to confirm TSC requirements.

Detector loops are required for each lane at the stopline, and must be compatible with SCATS operation. Counter loops must also be installed at un-signalised bypass slip lanes, and at the priority controlled legs where the roundabout is under partial signal control. Consideration should also be given to installing advance queue detectors on critical legs, where high or irregular demand is forecast, or where queuing risks impacting the operation of upstream intersections.

Other aspects of traffic signal design should be in accordance with the Main Roads Vehicular Signals Design Guidelines (Main Roads, 2024a), and the relevant Australian Standards and Austroads Guidelines as referenced in the Main Roads guidance.

An example Traffic Signal Arrangement (LMA) drawing is provided in Appendix C. This shows the LMA for Eelup Rotary in Western Australia, which demonstrates a typical traffic signal hardware setup, including displays, pole locations, control position and detector arrangements.

10 TRAFFIC ANALYSIS

The Operational Modelling Guidelines (Main Roads, 2021b) provide further detail and guidelines for the development of traffic models using a variety of modelling platforms. These include:

1. Information on the recommended modelling software, parameters and methodology in the development of SIDRA, LinSig, Vissim and Aimsun models.
2. Information on model instruction sheets that are used to confirm Main Road's modelling requirements at different stages of the design process.
3. Information on traffic model checklists that need to be populated by the modeller and the auditing engineer.

Additional information specifically relevant to signalised roundabouts is provided below.

10.1 Traffic Data

Unless agreed otherwise by Main Roads, classified traffic count surveys are required for the peak hour(s) used for analysis. At a minimum, these should include full vehicle classifications and should not be older than 12 months from the date of analysis, unless otherwise agreed by Main Roads. A 24-hour survey should also be undertaken to understand critical information such as K-factors (also known as 'peak hour percentages'). Queue lengths on all approaches and all lanes should be recorded for the peak periods to assist with base model calibration.

Modelling requirements with respect to the inclusion of upstream or downstream intersections should be discussed with Main Roads. If more than one intersection is required to be modelled (as a network), then either an origin-destination survey may need to be undertaken, or TomTom used to extract this data. Specific modelling requirements should be agreed with Main Roads.

10.2 Horizon Years and Traffic Forecasts

For future planning and major projects, the horizon years that should be applied for the purpose of traffic forecasts, capacity analysis and performance targets are:

- Project Case – 15 year horizon from project opening
- Ultimate Case – Horizon year to be determined by Main Roads Road Planning Branch

For roads and intersections controlled by Main Roads, any deviation from these horizon years will require Main Roads approval.

For operational assessment, including modification to existing traffic signals that fall under the Main Roads Traffic Signals Approval Policy, the Short Term Horizon and Medium Term Horizon requirements shall apply.

Future traffic flow forecasts may be available from Main Roads' demand/strategic models, which can be supplied to the study team for further calibration. In the absence of these forecasts, the study team may need to consider traffic growth in the area as well as background traffic growth to estimate future demand.

It is recommended that the study team consult with Main Roads to confirm forecast traffic flows and future year traffic data prior to undertaking modelling assessments.

10.3 Preliminary Capacity Analysis

An initial appraisal of the suitability of the roundabout for full signalisation may be based on the capacity check methodology outlined in Section 7.3.

10.4 Performance Criteria

Performance criteria for intersection design and operation is based on three key criteria discussed below; Level of Service, Degree of Saturation and Length of Queues.

Level of Service (LOS)

The Level of Service (LOS) measure for intersections is "control delay" (measured in seconds) and is a measure of the driver discomfort, frustration, fuel consumption and increased travel time. As control delay increases, LOS worsens. LOS for intersections, based on Austroads Guide to Traffic Management Part 3: Transport Study and Analysis Methods (Austroads, 2020a) is given in Table 10-1 below.

Level of Service	Control delay per vehicle in seconds (d) (including geometric delay)		
	Signalised Intersections (including Signalised Roundabouts)	Priority Controlled Intersections	Roundabouts (unsignalised and metered roundabouts)
A	d ≤ 10	d ≤ 10	d ≤ 10
B	10 < d < 20	10 < d < 15	10 < d < 20
C	20 < d < 35	15 < d < 25	20 < d < 35
D	35 < d < 55	25 < d < 35	35 < d < 50
E	55 < d ≤ 80	35 < d ≤ 50	50 < d ≤ 70
F	d > 80	d > 50	d > 70

Source: (Austroads, 2020a)

Table 10-1: Level of Service Definitions based on delay

A signalised roundabout (including those under full and partial signal control) should be considered a signalised intersection for the purpose of performance assessment against the LOS bands in Table 10-1 above. It should be noted that the delay for a particular LOS at signalised intersections is higher than the delay for the corresponding level of service at a priority controlled intersection or roundabout. This is because drivers tend to expect (and tolerate) higher delays at signalised intersections compared with non-signalised intersections. Analysts need to be aware of this when comparing results using packages that only report the intersection delay, and not the level of service as defined in Table 10-1.

Degree of Saturation (DOS)

The Degree of Saturation (DOS) is defined as the ratio of *demand flow to capacity* (also known as the volume to capacity ratio – *v/c ratio)* for any particular lane. The movement DOS is the largest DOS for any lane of the movement. The approach DOS is the largest v/c value for any movement (or lane) in the approach and the intersection DOS is the largest v/c value for any approach.

Length of Queues

This is of particular importance in assessing storage within the internal circulating lanes, to ensure queuing does not block upstream nodes of the roundabout. It is also important for assessing requirements for the length of any auxiliary lanes on external approaches. The 95% queue length is generally adopted as the minimum storage requirement, however longer lane lengths may be required for deceleration of vehicles on external approach legs. If the intersection is being modelled in LinSig, the Mean Maximum Queue for each lane should be assessed against the available storage.

Performance Criteria

For future planning and major projects, the performance criteria outlined in Table 10-2 shall apply to the analysis based on traffic volumes in the Project Case and Ultimate Case horizon years (refer to Section 10.2). For modification to existing intersections, including signalisation of existing roundabouts, the performance criteria outlined in the Main Roads Traffic Signals Approval Policy should be applied, based on the short and medium term horizons. For roads and intersections controlled by Main Roads, the design horizon year and performance criteria requirements should be confirmed with Main Roads.

Intersection Control	Criteria	Project Case Horizon Year	Ultimate Case Horizon Year
All Intersections	Intersection average LOS	D or better	E or better
All Intersections	Individual turn movement LOS	E or better	E or better for major road movements F or better for minor road movements
Signalised Intersections	Degree of saturation	≤ 0.9	≤ 1.0
Roundabouts	Degree of saturation	≤ 0.85	≤ 0.95

Table 10-2: Intersection Traffic Performance Criteria for Project Case and Ultimate Case

For the purpose of performance analysis for signalised roundabouts, the criteria for Signalised Intersections in Table 10-2 shall apply for all signalised legs of a roundabout. For unsignalised (priority-controlled) legs, the criteria for Roundabouts in Table 10-2 shall apply.

A sensitivity analysis to consider the implications of higher volumes may need to be considered where there is uncertainty regarding design volumes or future traffic growth.

10.5 Lane Flow Diagrams

As outlined in Local Transport Note 1/09 - Signal Controlled Roundabouts (Department for Transport, 2009), lane flow diagrams are a useful tool to understanding lane choice between the intersection nodes of a roundabout. At simple intersections with traffic signals, a multilane approach can often be modelled, as a single link as traffic will distribute itself evenly between the available lanes. At signal-controlled roundabouts, the choice of lane, both on the approaches and on the circulatory carriageway, is dependent on the intended exit for an individual vehicle.

Lane flow diagrams are used to assign movements to appropriate lanes from entry to exit, and thus enable optimisation of lanes for a successful design. An example of a lane flow diagram is shown in Figure 10-1. The origin destination matrix is shown in the centre, and the critical lane flow sums are shown in the green boxes at the centre of each intersection.

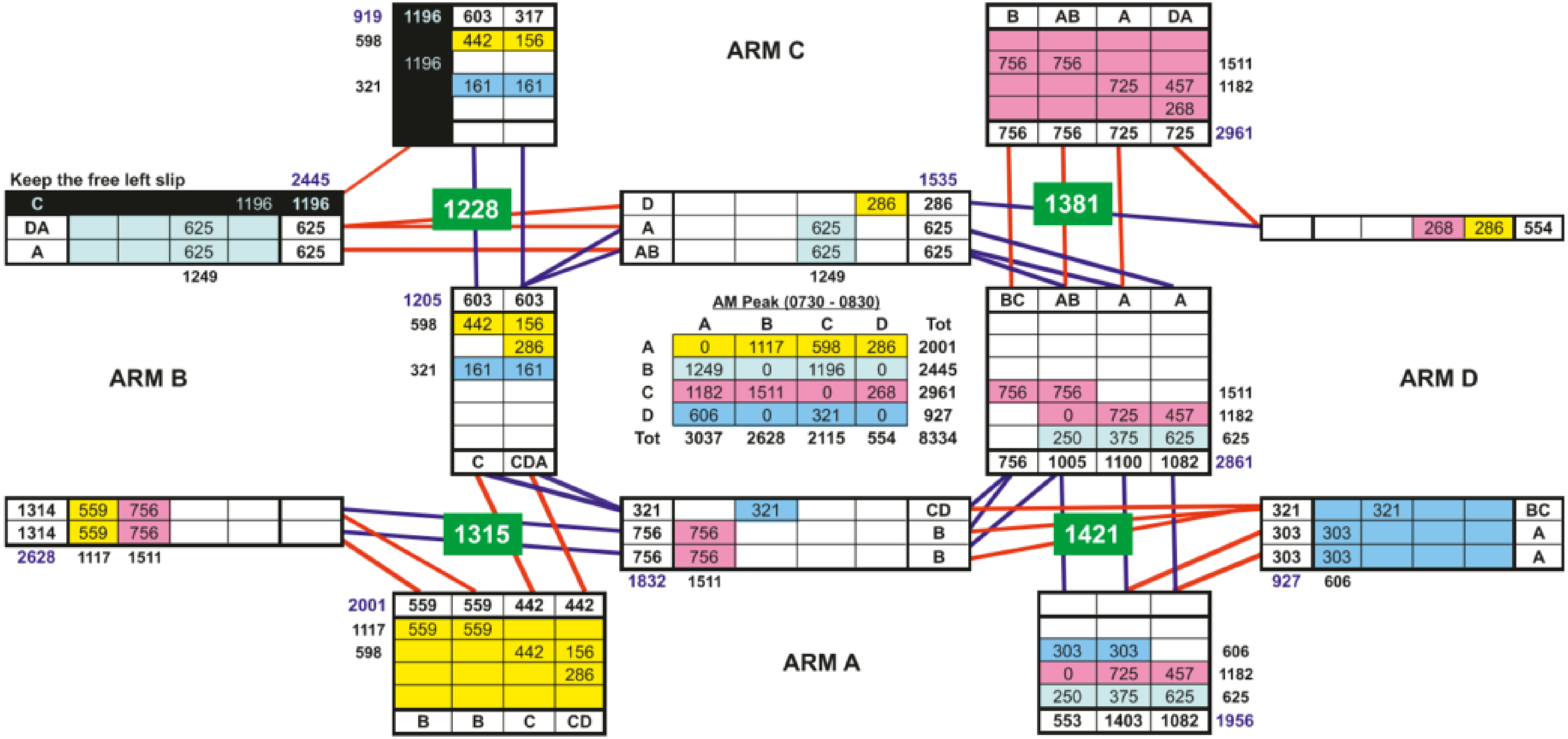


Figure 10-1: Example Lane Flow Diagram (source: Department for Transport, 2009)

The following guidance is adapted from Local Transport Note 1/09 - Signal Controlled Roundabouts (Department for Transport, 2009):

- These diagrams indicate how traffic will distribute itself on the approaches and through the roundabout for a particular layout and lane direction markings. They can also provide an indication as to whether the proposed design results in a (within capacity) solution.
- Lane flow diagrams should be prepared for each of the traffic situations being modelled. Where flow patterns vary widely at different times of day, the final lane designations chosen will have to be a compromise between the different requirements.
- If lane flow diagrams are not carefully prepared, geometric designs might be produced which assume a lane usage that is unattainable in practice. This might result in the outcomes predicted by the modelling process not being achieved.
- The lane markings themselves are an integral part of any preliminary design. During the development of the design, different lane markings can be appraised to see which one provides the best balance of the flow between lanes. The lane markings will determine the connections between the boxes on the lane flow diagram which will need to be revised.
- At large roundabouts, for example where there are bridges over or under a motorway, some lane changing can take place to bring circulating lane flows more into balance. Additional connectors in the lane flow diagram are used to allow or indicate such movements in a way that should be transparent for checking purposes.

10.6 Traffic Analysis and Modelling

Available forms of traffic modelling and assessment fall into two groups: deterministic/empirical models such as LinSig and SIDRA, and microsimulation models such as VISSIM and Aimsun. A high degree of expertise is required to operate these software packages, and it is essential that designers have experience in their use before preparing a design.

Essentially a signalised roundabout is a circular network of multiple signalised intersections within close proximity. In order to accurately review the interaction and potential blockages between these traffic signals, a microsimulation model is the preferred analysis software (as opposed to SIDRA or LinSig intersection models). It is recommended that prior to detailed design, or as part of a TSAP Stage 2 submission, a microsimulation model be developed for any signalised roundabout proposals. SIDRA and LinSig may be used at planning and concept design stages, and are generally considered adequate tools for assessing the feasibility of signalised roundabouts, comparing alternative intersection options, and preliminary development of intersection geometry, lane configuration and traffic signal settings.

Deterministic models (LinSig, SIDRA) provide direct output of signal timings and numerical results for many performance factors. Microsimulation models (VISSIM, Aimsun) provide dynamic representations of vehicle movements, and are particularly effective at modelling networks and the interaction between closely spaced intersections. It is important to note that microsimulation models do not necessarily have an optimiser to determine traffic signal settings (e.g. cycle and phase times) particularly on complex setups such as signalised roundabouts, so deterministic models may be an important step in providing this preliminary information.

An example of a VISSIM layout and phasing setup is shown in Figure 10-2 below.

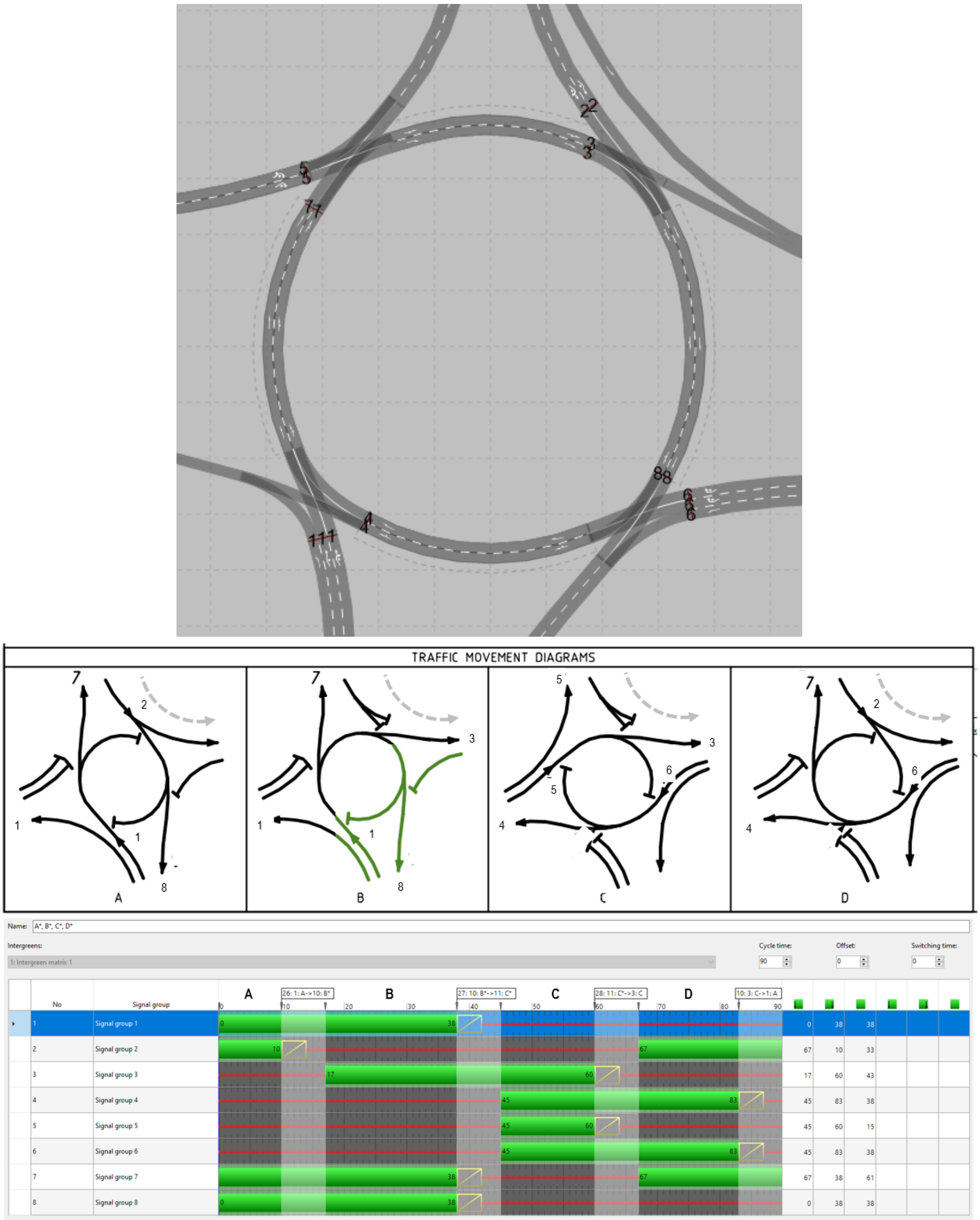


Figure 10-2: Example Model Layout and Phasing Setup – VISSIM (source: Urbsol, 2023)

Modelling of signalised roundabouts in LinSig offers a number of benefits including:

- Lane flow diagrams (as discussed in Section 10.5) can be set up using LinSig, providing a more integrated and interactive process.
- Traffic flow is setup as an OD matrix (similar to a microsimulation model), providing more accurate lane allocation compared to SIDRA.
- LinSig offers interactive manipulation of phase timings, providing instant results at each step, including cyclic platoon and queue graphs.

LinSig also has some limitations, including not capturing the effects of downstream blocking. When optimising for cycle times and phase splits, this limitation could produce incorrect results.

There are manual techniques used, particularly around signalised roundabouts to ensure that internal storage queues are retained and not exceeded.

An example of a LinSig junction setup is shown Figure 10-3 below (based on LinSig version 2.3).

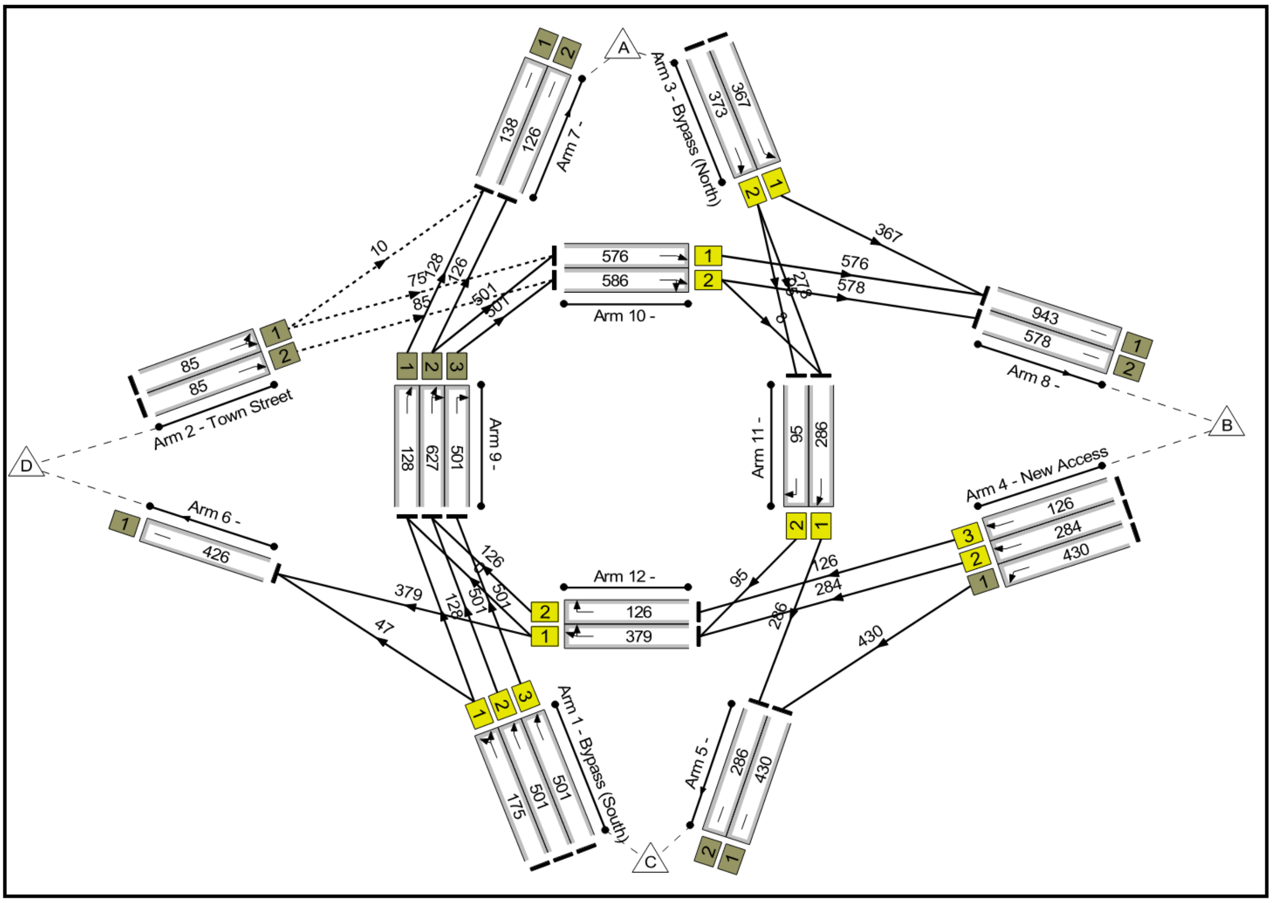


Figure 10-3: Example Junction and Lane Flow Setup – LinSig version 2.3 (source: JCT Consultancy, 2007)

It is also possible to model signalised roundabouts using SIDRA, although there are some limitations, such as the default in SIDRA to achieve balanced (equal) lane allocation at all approach legs, which can therefore encourage significant lane changing between signalised intersections. In reality there should be very low lane changing behavior, unless auxiliary right turn pockets within the roundabout are provided. Hence it is very important that special movement classes for each major OD pair are utilised in SIDRA to allocate the right-turning vehicles into the correct entry lanes, and then into the correct circulating lanes. Modellers should also review lane changes and mid-block flows to ensure minimal lane changes. .

An example of a SIDRA layout and phasing setup is shown in Figure 10-4.

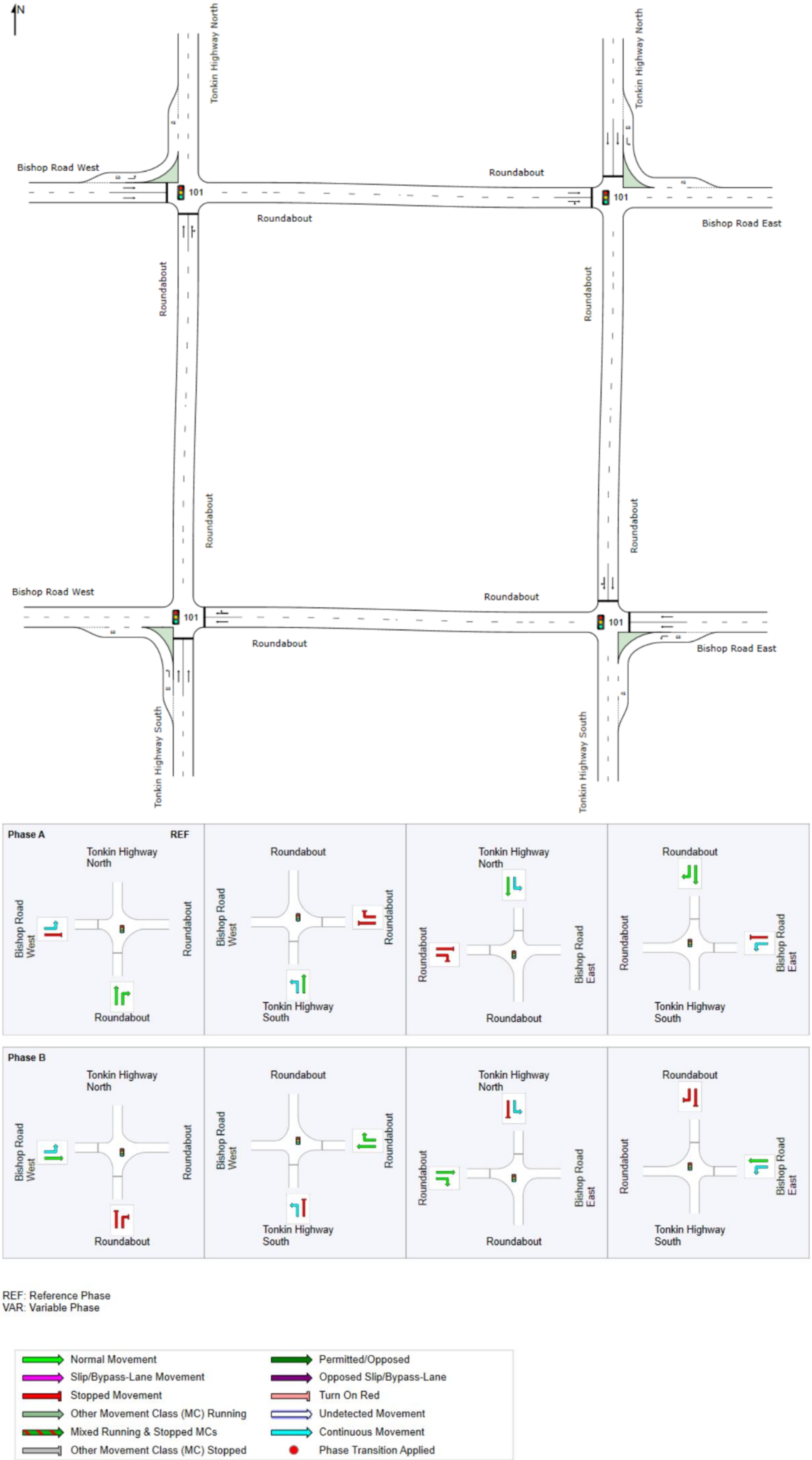


Figure 10-4: Example Model Layout and Phasing Setup – SIDRA

Irrespective of the software choice, the model will need to treat each node as a separate intersection, and therefore origin-destination matrices will be required to understand traffic progression through the intersections, and expected lane choice and thereby lane utilisation. The lane flow diagram discussed in Section 10.5 is an important input to the model setup.

The modelling outputs should include, as a minimum:

1. A comparison of the different options, for all scenarios, with regards to:
    - Level of Service (LOS) and associated average delay
    - Degree of Saturation (DOS)
    - 95th percentile queue lengths
    - Cycle and phase times
2. A breakdown of the above by lane for each model scenario.

There is also a likelihood that the results and even outcomes may vary across the modelling tools – this should be considered during the scoping, modelling and decision-making processes, requiring professional judgement in analysis and interpretation.

10.7 Traffic Signal Approval

Main Roads' Network Operations Directorate must formally approve all permanent traffic control signal installations, modifications or removals on public roads in WA. Refer to the "Traffic Signals Approval Policy" (Main Roads, 2021c), which sets out the circumstances under which Main Roads will consider approving the modification of existing traffic signals and the provision of new traffic signals on all roads in Western Australia.

11 SIGNALISED ROUNDABOUTS WITH NO INTERNAL STORAGE

This section covers the full signalisation of small to medium sized diameter roundabouts (typically less than 50 m), which will typically provide inadequate space for internal storage. In this scenario, signalisation without internal storage may be considered. This typically requires traffic signal operation whereby all entries run separately in an anti-clockwise fashion. Such operation will be significantly less efficient due to this phasing arrangement, which introduces longer clearance times and associated higher inter-green times, and generally lower saturation flow as a portion of the circulatory lanes are being used at any one time. However signalised roundabouts with no internal storage may be considered as a retrofit to existing roundabouts under the following conditions:

- Significant pedestrian demand (refer to footnote 1 in Section 5.1).
- Corridor or network benefits associated with providing signals that are linked with other traffic signals along the corridor.

The signalised roundabout must meet the following design criteria:

- Achieve adequate operational performance under the design demand (as per Section 10).
- Adequate storage is available on each external leg without compromising upstream intersections or access.
- Safe pedestrian crossings can be provided across each leg.

11.1 Capacity Considerations

A signalised roundabout with no internal storage has limited capacity, due to the relatively inefficient signal phasing operation. For planning purposes, evaluation of total volume through the intersection can be compared to the probable capacity, as shown in Table 11-1 below. Actual capacity can vary depending on the roundabout diameter, heavy vehicle composition, and split of demand between each approach leg. Traffic modelling in accordance with Section 10 should be undertaken to demonstrate adequate capacity and operational performance for the peak periods can be achieved.

Combined Volume on all External Approach Legs – Single Lane Roundabout	Combined Volume on all External Approach Legs – Two Lane Roundabout	Relationship to Probable Capacity
0 to 1,300 vph	0 to 2,000 vph	Under Capacity
1,301 to 1,500 vph	2,001 to 2,700 vph	Near Capacity
>1,500 vph	>2,700 vph	Over Capacity

Table 11-1: Capacity Thresholds for Signalised Roundabouts with No Internal Storage

11.2 Geometric Design Considerations

This intersection treatment provides good access for pedestrian across the approach legs, as three of four legs will be under red light control (allowing pedestrians to cross) while the other leg is discharging. However the departure legs require more careful consideration. Options could include:

- Providing a priority pedestrian crossing (zebra, wombat or signalised pedestrian crossing) at least two or three car-lengths downstream of the roundabout, allowing vehicle stacking

without compromising traffic flow in the circulating lanes. The signalised pedestrian crossing would likely be activated when the approach lanes on the same leg is activated for vehicles, i.e. only u-turning vehicles should stack in front of the pedestrian crossing. If the roundabout caters for a significant number of u-turning vehicles, a greater setback may be required (refer also Section 8.4).
- For very busy areas such as city centres or activity centres, an exclusive pedestrian phase with green pedestrian phase across all legs simultaneously.
- Uncontrolled pedestrian crossings, where traffic volumes are suitably low, resulting in adequate gaps for pedestrians to make the crossings.
- Providing a pedestrian walkway in the central island so that pedestrians can avoid crossing the departure legs.

11.3 Operational Considerations

The proposed phasing diagram for signalising small diameter roundabouts is shown in Figure 11-1. Some considerations for this phasing include:

- A longer cycle time can be adopted, as stacking is only limited by the storage. E.g. a standard cycle time of 1 to 2 minutes is likely to be appropriate.
- It may be possible to start the green phase for each approach leg with a slight overlap to the preceding phase, based on the geometric offset between the potential conflict zone, noting the internal legs will also need to be offset to allow vehicles to clear the roundabout.
- Standard inter-green time is required. This is typically 4 s yellow and 2 s red, however should be calculated based on the circulatory design speed and intersection clearance distance in accordance with Austroads Guide to Traffic Management Part 9: Transport Control Systems – Strategies and Operations (Austroads, 2020c).

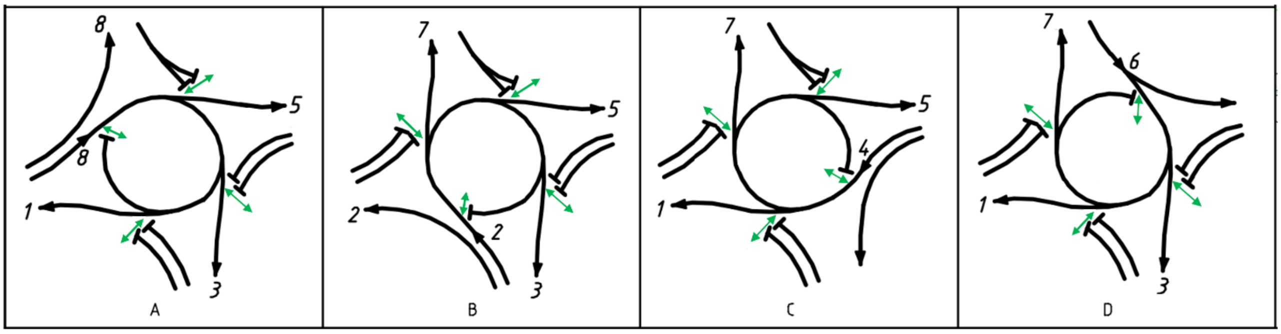


Figure 11-1: Traffic Movement Diagram – Four-Phase Operation for Roundabouts with no Internal Storage

An example of a small diameter signalised roundabout is shown in Figure 11-2 below. This roundabout has a central island diameter of 25 m, and most internal storage legs would only allow one light vehicle to prop without interfering with the circulating flow from the upstream leg.

Figure 11-2: Example Small Diameter Signalised Roundabout – Mickleham Road and Melrose Drive, Tullamarine, Victoria (source: Google Maps)

12 REFERENCES AND RELATED DOCUMENTS

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Austroads, 2017b	Guide to Traffic Management Part 6: Intersections, Interchanges and Crossings. Austroads, 2017. AGTM06-17.
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Document Reference	Description
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Main Roads, 2021a	Main Roads' Road Trauma Treatments Guideline, Main Roads Western Australia, December 2021. TRIM Ref: D15#68384.
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Main Roads, 2023a	Main Roads Supplement to Austroads Guide to Road Design Part 4 – Intersections and Crossing (Main Roads, 2023)
Main Roads, 2023b	Guidelines for Pedestrian Crossing Facilities at Traffic Control Signals. Main Roads Western Australia, 2023.
Main Roads, 2024a	Vehicular Signals Design Guidelines. Main Roads Western Australia, 2024.
Main Roads, 2024b	Lighting Design Guideline for Roadway and Public Spaces. Main Roads Western Australia, 2024.
Main Roads, 2025	Towards a Safe System Approach - Selection of Intersection Control Guidelines, Main Roads Western Australia, 2025. TRIM Ref: D17#823038.
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13 APPENDICES

Appendix	Title
Appendix A	Case Studies
Appendix B	Worked Example
Appendix C	Example LMA (Traffic Signal Arrangement) and LMB (Signage and Pavement Marking) Drawings

Appendix A: Case Studies

Case Study 1: UK Example - Partial Control Roundabout

The roundabout of Keith Street, Palace Grounds (A72), Motherwell Road (A723) and Blackswell Lane in Hamilton, Scotland, UK, as shown in Figure A.1 below, has been operating under signal control for over 20 years. This is an oval roundabout with central island diameter of 70 m on the shortest leg, and 85 m on the longest leg.

Originally this roundabout operated with all four legs under signal control, however an imbalance in traffic flows (a very high demand from the north leg, primarily for left-turning traffic), was leading to high cycle times being required, causing internal queuing and blocking issues. Traffic analysis was undertaken to demonstrate that traffic progression through the roundabout was improved by removal of signal control of the west leg – allowing fewer phases, shorter cycle times, and a reduction in the risk of internal legs blocking back to upstream intersections. Demand from the west leg was a maximum of 350 vph in the peak hours, less than 7% of the total intersection demand.

An unconventional phasing plan is adopted, as shown in Figure A.2. Rather than a standard north-south A-phase, the east external leg runs with the north external leg under A-phase, which allows the heavy demand from the north to operate with the heavy demand from the east. The B-phase then allows all internal queues to be cleared.

Further details on the modelling and implementation of this roundabout signal can be found in the paper 'Signal Controlled Roundabouts: Breaking the Rules' (O. Riccomini, B. Chard, 2009).

Figure A.1: Roundabout Signals at the Hamilton Roundabout, Scotland (source: Google Maps)

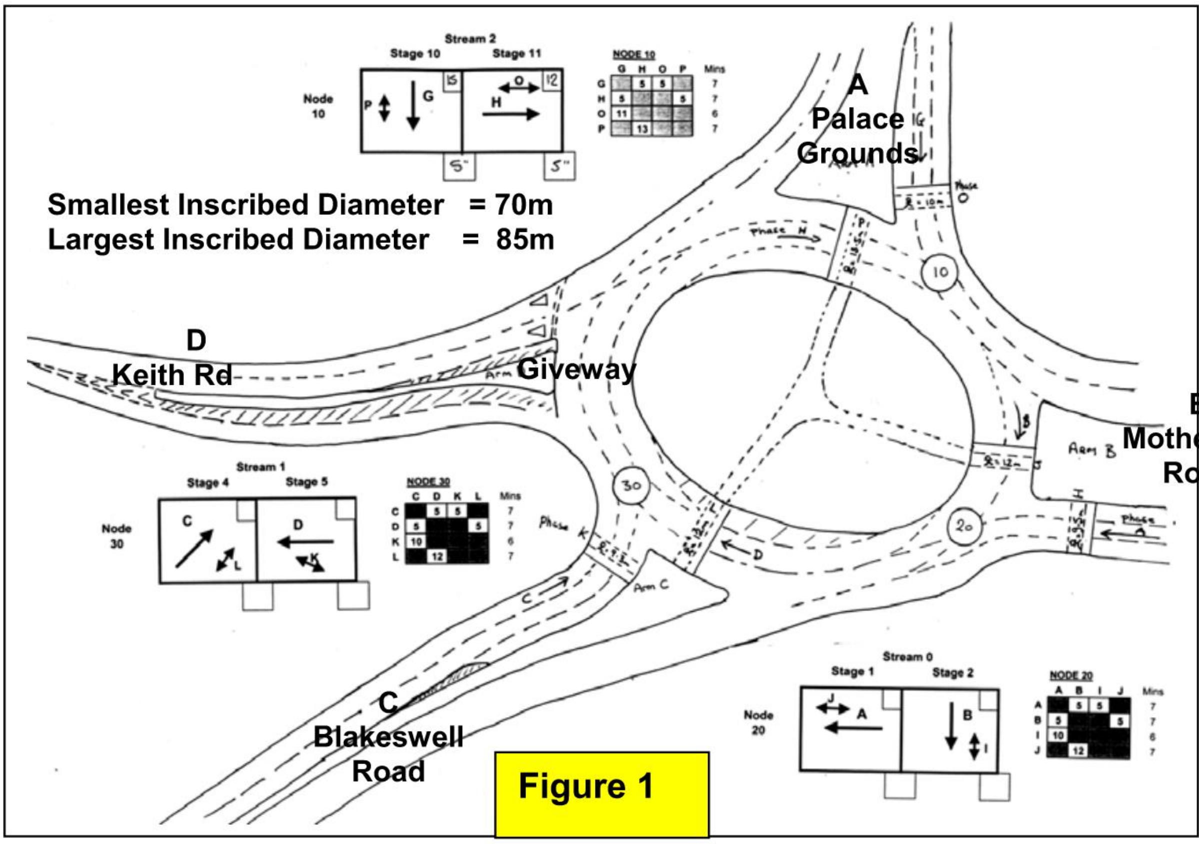


Figure A.2: Layout and Signal Plan for Roundabout Signals at the Hamilton Roundabout, Scotland (source: O.Riccomini, B Chard, 2002)

Case Study 2: New Zealand Example - Small-Diameter Roundabout with Limited Internal Storage

Roundabout metering was installed at two roundabouts on the Welcome Bay Corridor in Tauranga, North Island, New Zealand, in 2008. This includes the Maungatapu Roundabout (approximately 90 m central island diameter) at the intersection of Maungatapu Road / State Highway 29, in Tauranga, and the Welcome Bay Roundabout (36m central island diameter) at the intersection of Welcome Bay Road / State Highway 29 / Hairini Street. Both intersections were experiencing significant congestion, with queues at the Welcome Bay Roundabout often blocking the operation of the Maungatapu Roundabout.

For the Welcome Bay Roundabout, the existing roundabout layout was flared from 2 circulatory lanes to 3 lanes in the northbound and southbound direction, to cater for internal storage. This required the central island width to be compressed in the east-west direction. Given the low demand from Hairini Street (maximum 80 vph in the peak hour), this was retained as a priority controlled approach, which allows the signals to operate with a simple two-phase operation, as shown in Figure A.3 below. The signals operate with average 60 second cycle times during the AM and PM peak periods, and cycle times ranging from 35 to 50 seconds in the off-peak and intra-peak periods. A total of 8 scheduled cycle plans were developed to cater for the variation in traffic demand across weekdays and weekends. North and south traffic operates during Phase A, with a 12 second stagger in start times to allow any right turning traffic from Welcome Bay Road (east leg) to clear before the northbound leg starts. Phase B caters for the east leg, as well as any u-turning traffic form the side road to the southeast, from which right turning traffic is banned due to the proximity of the roundabout (and hence has to U-turn through the roundabout.)

Further details on the modelling and implementation of these roundabout signals can be found in the paper '[Signal Controlled Roundabout Methodology and its introduction to NZ at Welcome Bay, Maungatapu and Brookfield Roundabouts in Tauranga North Island]' (B. Chard et al, 2009).

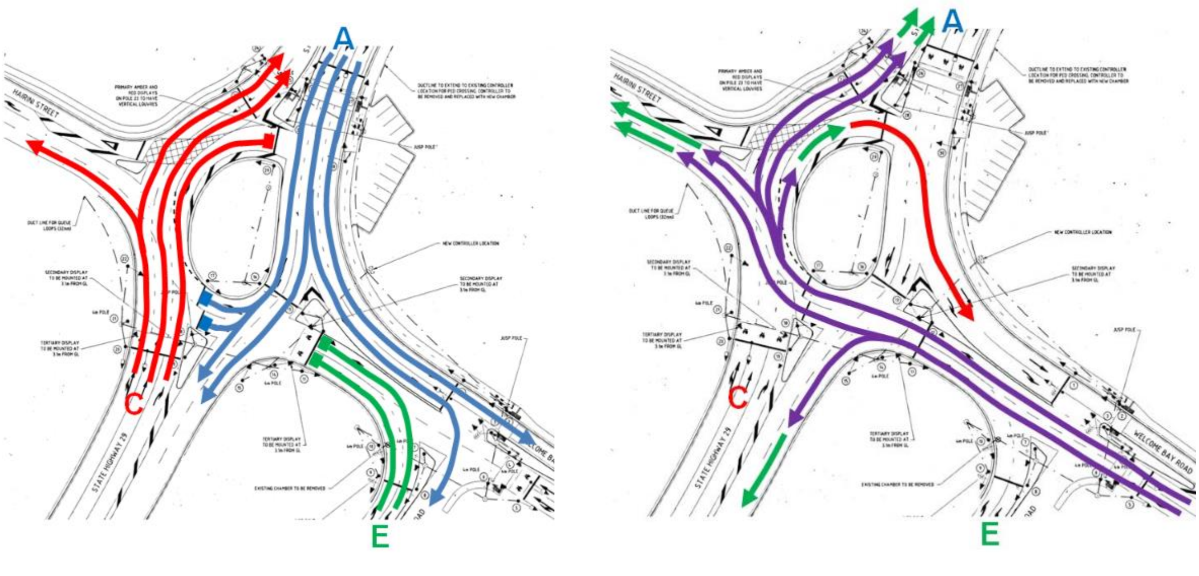


Figure A.3: Traffic Progression through the Linked Signals at Welcome Bay Roundabout (source: B Chard, 2009)

Case Study 3: East Coast Example - Canberra

Roundabout signalisation was installed at the intersection of Barton Highway, Gundaroo Drive and William Slim Drive in Canberra in 2016. The roundabout has a central island diameter of approximately 60 m, and three circulatory lanes on the internal legs.

The existing priority controlled intersection (pre-2016) was experiencing heavy congestion in the peak periods due to unbalanced flows, creating length queues and delays on the heavily trafficked legs, and led to an increase in the frequency of crashes. Upgrade to signalisation included additional circulatory lanes to cater for queue storage, and signal optimisation to balance the approach flows and reduce queuing and delays. On-road cycle lanes were also introduced to provide for safe passage for cyclists. Bus-only priority lanes were provided on the east leg.

The existing roundabout was Canberra's most dangerous intersection, recording the most crashes, at 515, between 2010 to 2014. Initial safety assessment showed crashes at the roundabout reduced by about half in 2017, compared to the average over the three years prior (O'Mallon, F. 2018).

Further details on the roundabout signalisation upgrade, cost and BCR analysis outcomes can be found in the 'Barton Highway / Gundaroo Drive / William Slim Drive Roundabout Upgrade Fact Sheet' (ACT Government, 2015).

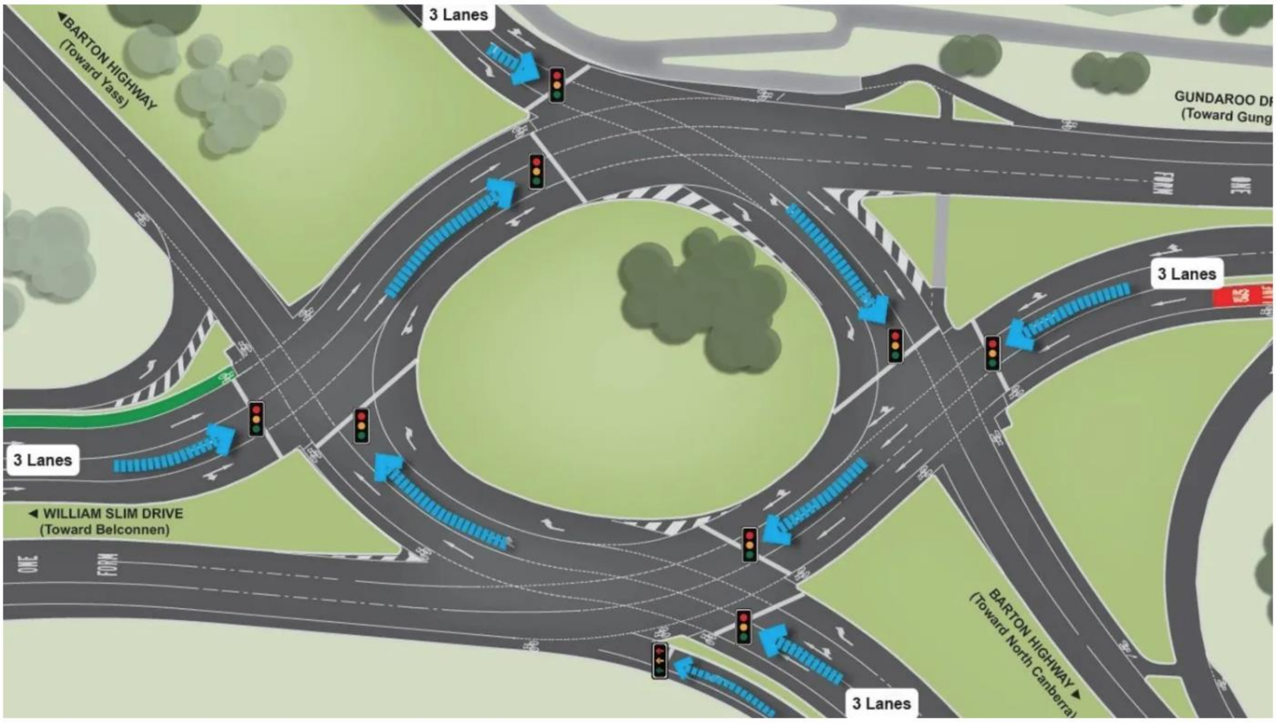


Figure A.4: Roundabout Signals at Barton Highway / Gundaroo Drive, Canberra (source: The Age, accessed 2024)

Case Study 4: Western Australia Example - Eelup Rotary

Prior to signalisation, the Eelup Rotary in Bunbury had an extremely poor crash record (albeit the vast majority of crashes were property-damage only) and was frequently congested during the peak periods. The roundabout also experienced issues with poor upstream lane choice (and lane-changing within the roundabout, causing safety issues), and congestion during the peak holiday periods where the roundabout is subject to very high tidal demand, quite different to its normal weekday operation. The major problem identified was that large multi-combinational vehicles struggled to "pick a gap" in the circulating traffic stream because of the high traffic volumes and high circulatory speeds. The large central diameter of 180 m contributed directly to the high circulatory speeds. Figure A.5 shows the roundabout prior to upgrading.

Figure A.5: Eelup Rotary in 2011 prior to Upgrading

Design Proposals

An initial proposal to upgrade the roundabout had considered constructing a smaller roundabout within the existing central island in order to reduce the circulatory speeds. However, this would not have provided sufficient capacity and did not address the issue of truck drivers being able to "pick a gap" in the high circulatory flow.

A decision to signalise the roundabout was made based on the ability to utilise the existing pavement area effectively as well as taking advantage of the large internal storage area to store turning traffic. In addition, this catered well for future east-west grade separation plans. In 2011 construction commenced to upgrade the roundabout to a signalised roundabout. The main approaches were flared to three lanes and the circulating roadway was widened to three lanes in three of the four quadrants. In addition, left-turn slip lanes were provided for three of the four movements. The upgraded "roundabout" is shown in Figure A.6.

Figure A.6: Eelup Rotary in 2014 after Upgrading

Current crash records indicate a substantial reduction in the number of crashes and congestion during peak periods, including peak holiday long-weekend periods has largely been eliminated.

One of the key factors for the success of this roundabout was recognising the need to get drivers into the correct lanes prior to the roundabout. This was achieved using overhead advance direction signing, supplemented with pavement markings indicating destinations.

Figure A.7: Eelup Rotary showing Overhead Advance Direction Signs and Supplementary Pavement Markings

Appendix B: Worked Example

Example 1: Application of Roundabout Capacity Preliminary Check

A worked example is shown below, for the intersection of Marmion Avenue and Shenton Avenue in Ocean Reef, Western Australia. This example is only used to illustrate the roundabout diameter and capacity preliminary checks outlined in Sections 7.3 and 7.4. It does not consider the suitability criteria or whether there is reasonable justification for installing roundabout signalisation at this location. This roundabout has a 50m central island diameter, with a standard two lane layout, with shared left / through and shared through / right lanes on all approaches, as shown in Figure B.1 below.

Figure B.1: Marmion Avenue / Shenton Avenue Roundabout (Ocean Reef, W.A) source: Google Maps

The first check is to use Figure 7-1 to test whether a signalised roundabout is likely to provide adequate capacity to cater for the peak hour traffic volumes, considering the proportion of right turning vehicles at the intersection. Traffic volumes used for this preliminary check are based on existing peak hour turn count data from November 2023, and do not consider future growth. Assessment of the forecast year demands should also be undertaken. Existing traffic demands are shown in Figure B.2 below.

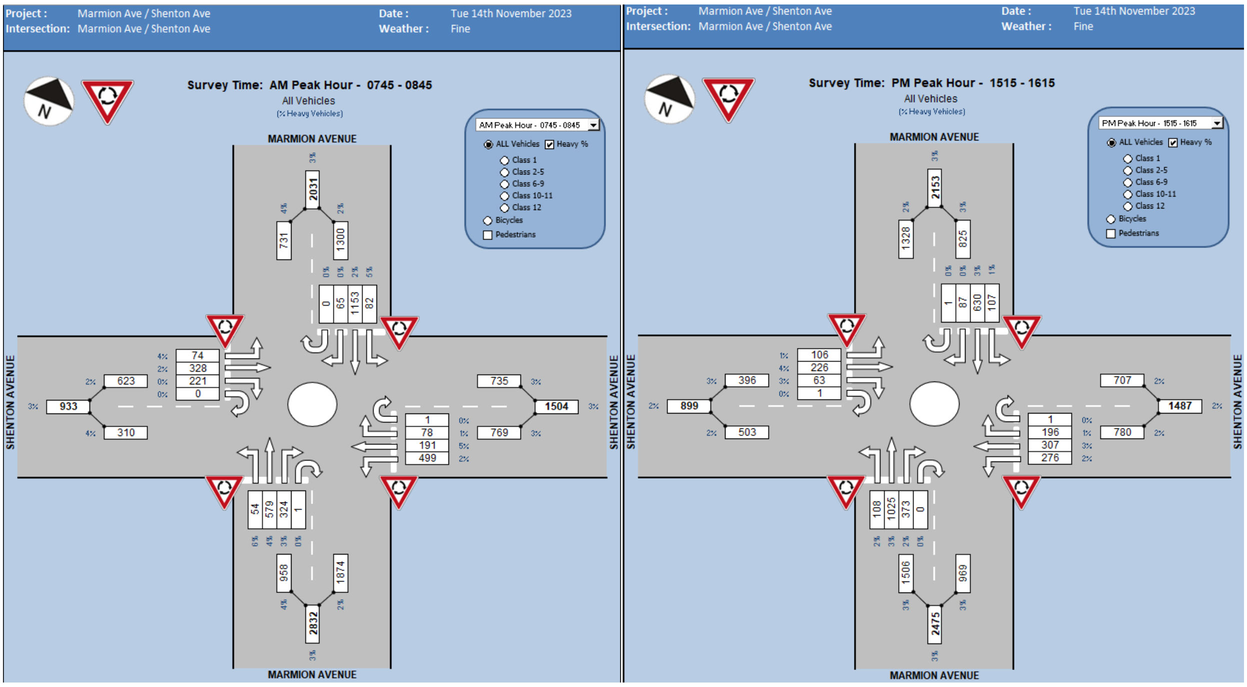


Figure B.2: Intersection Peak Hour Turning Volumes (Left: AM Peak, Right: PM Peak)

The peak hour demands are plotted against the preliminary capacity chart (Figure 7-1), as shown in Figure B.3 below. The total intersection demand (the combined volume of all external approach legs) is plotted against the average proportion of right turn demand, which is approximately 19% in the AM peak and 21% in the PM peak. Where these lines intersect is below the indicative capacity threshold of a signalised roundabout with two circulating lanes, as shown by the green band, and therefore this roundabout is likely to provide adequate capacity as a signalised roundabout. The approach leg with the maximum right turn proportion is also indicated as dashed line; in the AM peak the west leg has 34% of total approach volume turning right, while in the PM peak the south and east legs have 25% of total approach volume turning right. As shown, the west leg with a 34% right turn demand is just within the threshold band for a two lane circulating roundabout, which may indicate that additional capacity (or green time) may be required for this leg.

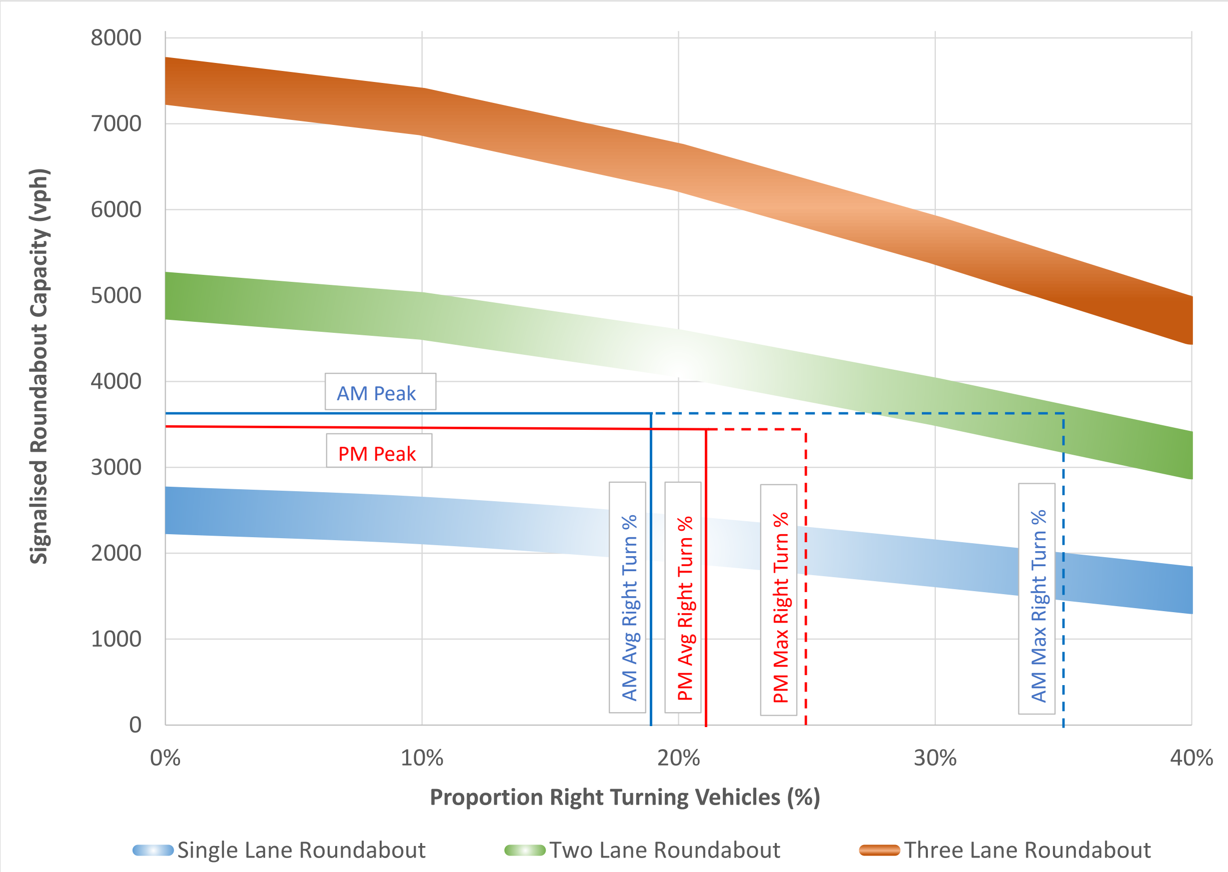


Figure B.3: Shenton Avenue / Marmion Avenue Roundabout - Preliminary Capacity Check

The second check is to test whether the roundabout is likely to have adequate diameter and storage capacity on the internal legs to operate with simple two phase signal operation, using Figure 7-2. For the Marmion Avenue / Shenton Avenue roundabout, the central island diameter (50m) is plotted against the maximum right turn demand for each approach leg (maximum peak hour volume across the 24 hour period), as shown in Figure B.4 below. This shows three of the four legs have right turn demand in excess of the internal storage capacity of the roundabout, and hence a two-phase operation is not viable at this intersection. To cater for the relatively heavy right turn demands on most of the approaches, it is likely that a four phase signal cycle will be required, similar to those shown in Figure 9-3 and Figure 9-4. While this will result in a less efficient operation, it does not preclude it from being converted to a signalised roundabout. Traffic modelling will be required to determine the most appropriate signal phasing, and whether widening for internal storage will be required to cater for the heavier right turn demands.

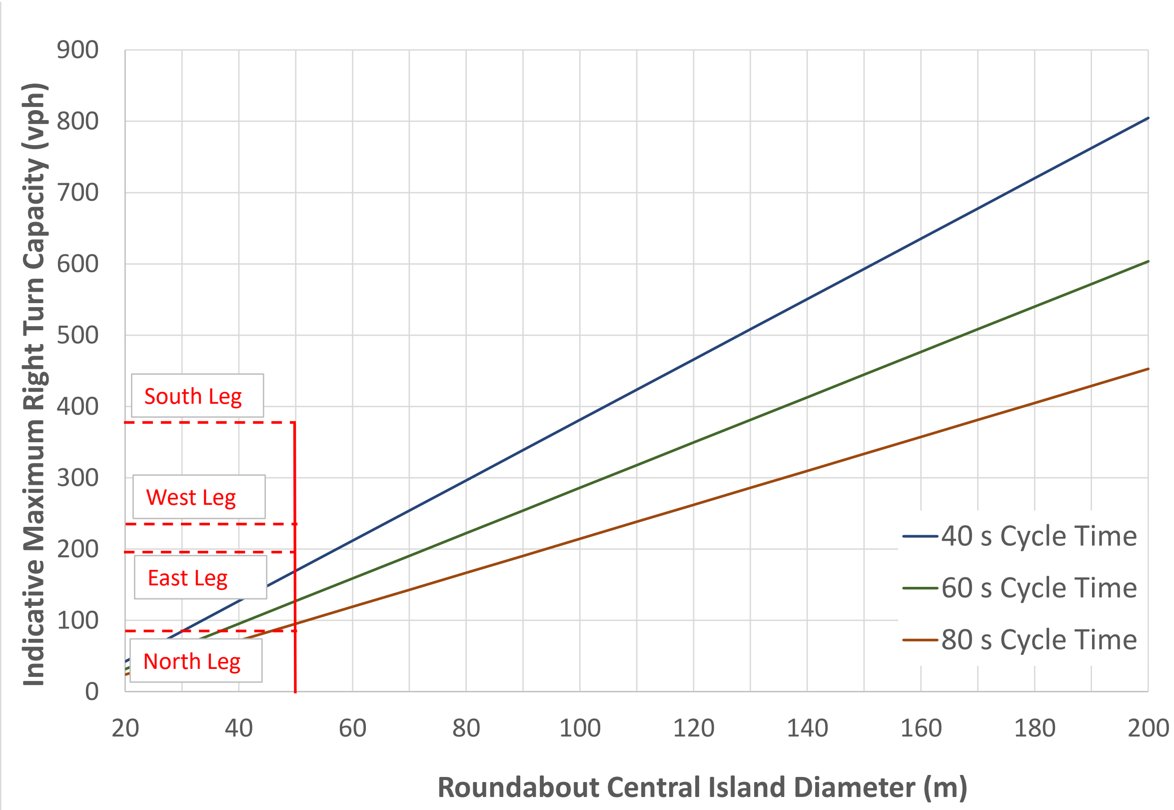
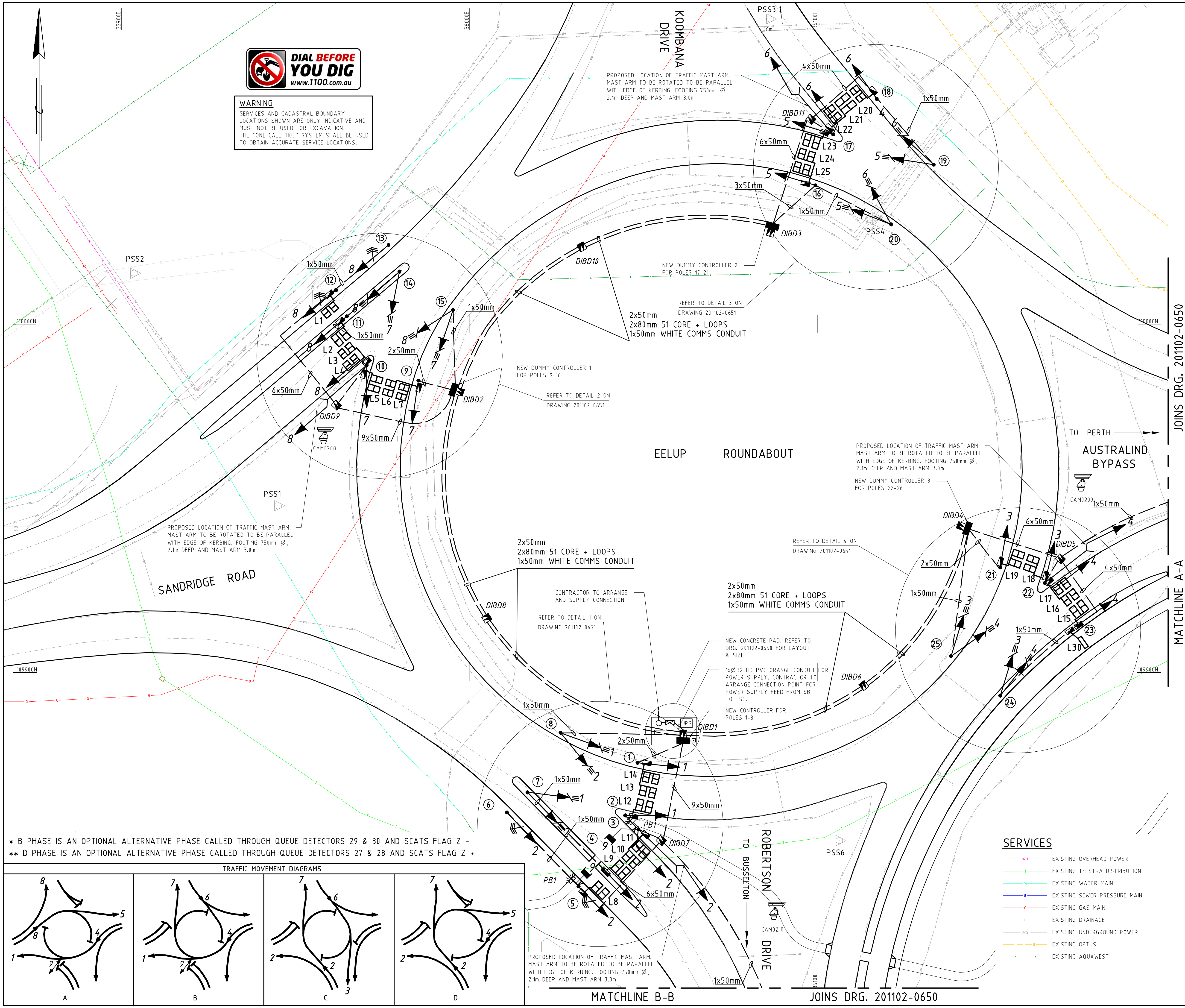


Figure B.4: Shenton Avenue / Marmion Avenue Roundabout – Preliminary Check or Right Turn Storage Capacity to Operate under a simple Two Phase Signal Cycle

Appendix C: Example LMA (Traffic Signal Arrangement) and LMB (Signage and Pavement Marking) Drawings

Example: Eelup Rotary, Bunbury, Western Australia



AMENDMENTS

No.	DATE	DESCRIPTION	APPROVED
0	2.11.2011	SAME AS TENDER DRAWING REV F.	LP
1	06.02.2012	CONDUITS AMENDED	DN
2	16.02.2012	CONDUIT QUANTITY AMENDED	DN
3	13.03.2012	WESTERN PED CROSSING DELETED	STT
4	02.04.2012	LOOP NUMBERS AMENDED	STT

NOTES

1. THIS DRAWING IS TO BE READ IN CONJUNCTION WITH THE MRWA SPECIFICATIONS.
2. INSTALL WALK/DONT WALK LANTERNS ON POSTS AS SHOWN
3. NEW AUDIO TACTILE PUSH BUTTONS TO BE POSITIONED TO THE SIDE OF THE POSTS SUCH THAT THE ARROW IS POINTING IN THE DIRECTION OF TRAVEL. AUDIO TACTILE DRIVER UNITS ARE TO BE INSTALLED.
4. ALL TRAFFIC LANTERNS ARE LED BASED, INCLUDING W/DW LANTERNS
5. ADDITIONAL DUMMY CONTROLLER TO BE INSTALLED AS SHOWN.
6. NEW STAR WIRING SYSTEM ADOPTED WITH 19 CORE POLE CABLES WIRED INDIVIDUALLY BACK TO THE CONTROLLER/DUMMY.
7. PROPOSED CONDUIT QUANTITIES ARE BORED INSTALLATION. A MINIMUM OF 1 SPARE CONDUIT TO BE INSTALLED ON THAT LEG.
8. PROPOSED NEW MAST ARMS TO BE TYPE 5L FOR POSTS 3,8,11 & 23
9. REFER TO MRWA STANDARD DWG NO.0330-1994 FOR MASTARM FOOTING DETAIL.
10. REFER TO DWG NO. 201102-0652 FOR MOUNTING PLATE DETAIL.
11. LUGS ON THE MAST ARM TO BE AS PER TAPERLINE CATALOGUE NUMBER: TYPE 5 MODIFIED.
12. FOR UPS BASE DETAILS REFER TO STANDARD DRG. 0748-3118.
13. INSTALL 200mm ANGLED VISORS ON TRAFFIC LANTERNS WHERE INDICATED.

JOINS DRG. 201102-0650

NEW SITE - LM1071

CONTROLLER	RTA TSC/4
LANTERNS	LED
COMMUNICATIONS	SCATS - FIBRE OPTIC

REFERENCES

DESCRIPTION	DRAWING No.
LEGEND (TRAFFIC SIGNALS)	8320-0400
LEGEND (SYMBOLS)	8525-0316 & 8525-0317
CONDUITS (STANDARD)	8420-0700
RAISED PAVEMENT MARKERS	9120-0158 & 9120-0159
PEDESTRIAN RAMP DETAILS	9331-380
KERBING TYPE	9331-376
CHANNELISATION	MRWA
TRAFFIC SIGNAL POLE AND LOOP LAYOUT	201102-0649 TO 651
MINOR SIGNING AND PAVEMENT MARKINGS	MRWA

METADATA

GROUND SURVEY STANDARD:	-
DATE OF CAPTURE:	2011
MAPPING SURVEY STANDARD:	67-08-43
DATE OF CAPTURE:	2011
MAIN ROADS PROJECT ZONE:	PCG-94
HEIGHT DATUM:	AHD

Government of Western Australia
mainroads WESTERN AUSTRALIA
SOUTH WEST REGION
ROBERTSON DRIVE BUNBURY 6230
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DRAWING NUMBER/DOCUMENT ID 61/26769

DESIGNED / DRAWN	P. VARDY	
VERIFIED	S. T. TAN	16.11.2011
DIRECTOR	S. T. TAN	16.11.2011
RECOMMENDED (MRWA)	L. PALANDRI	17.11.2011
APPROVED (MRWA)	B. BELSTEAD	18.11.2011

SCALES 1:500 — 0 5m 10 15 20 25 30 35 40 45 50 55 60 65 70 75

A1

PERTH - BUNBURY HIGHWAY (H002)

EELUP ROUNDABOUT INTERIM UPGRADE

160.64 SLK TO 161.82 SLK

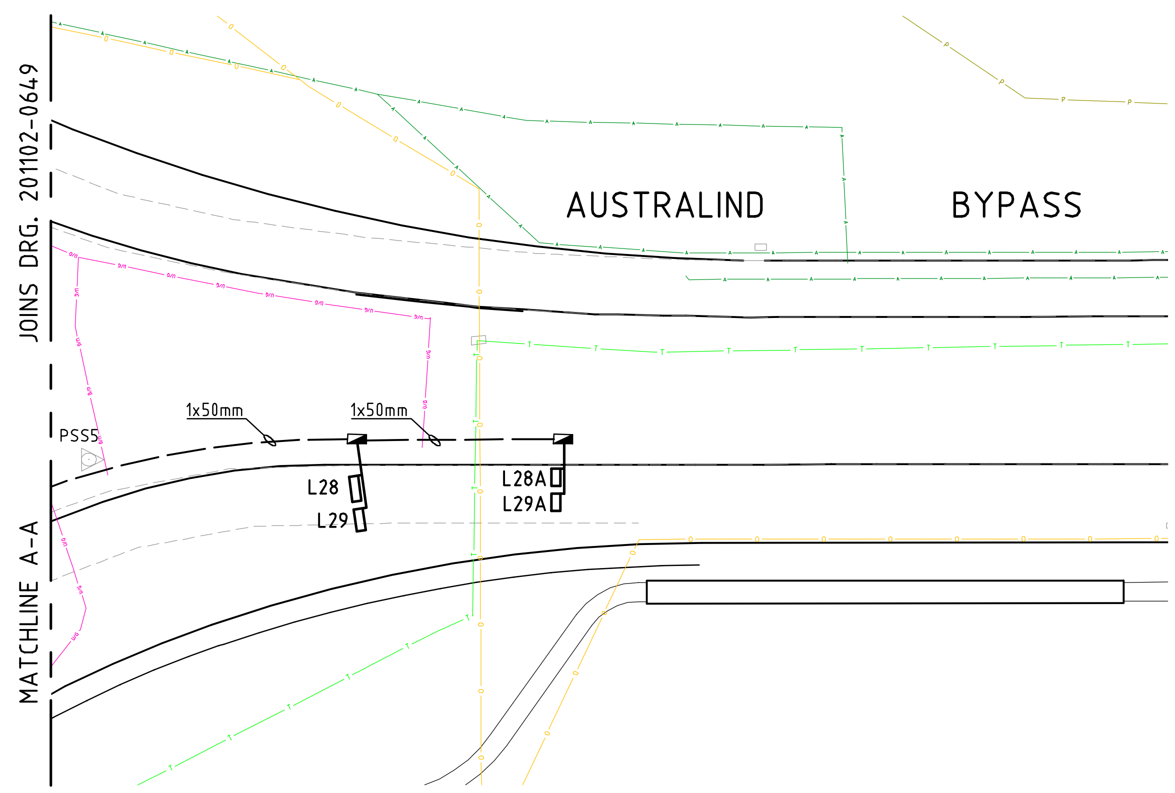
TRAFFIC SIGNALS

SHEET 1 OF 3

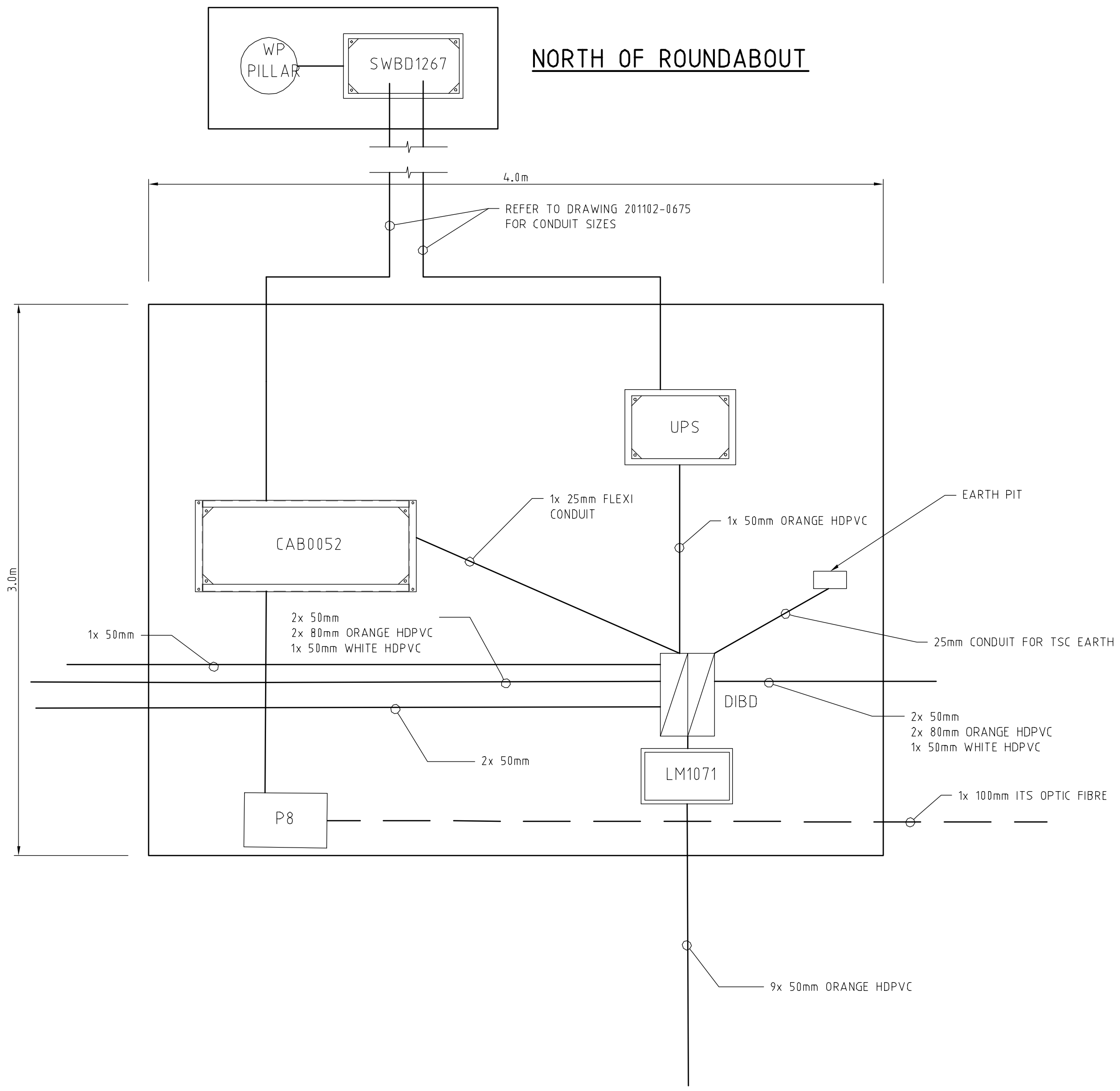
LOCAL AUTHORITY (204) CITY OF BUNBURY

MRWA DRAWING NUMBER

201102-0649-4



* L28 & L29 = 75m FROM STOPLINE
* L28A & L29A = 100m FROM STOPLINE



PAD DETAIL
SCALE 1:20

CONTROLLER & CABLE PIT LOCATIONS		
PITS	CO-ORDINATES	
	EASTING	NORTHING
■	*	*
DUMMY 1	35995.422	109981.109
DUMMY 2	36087.093	110028.031
DUMMY 3	36142.943	109941.155
DIBD5	36169.776	109932.500
DIBD6	36120.323	109901.629
DIBD7	36055.124	109851.599
DIBD8	36004.991	109915.494
DIBD9	35961.947	109976.675
DIBD10	36032.415	110022.059
DIBD11	36098.011	110058.777

* CONTROLLER POSITION TO BE CONFIRMED ON SITE IN CONJUNCTION WITH THE NEW CONCRETE PAD

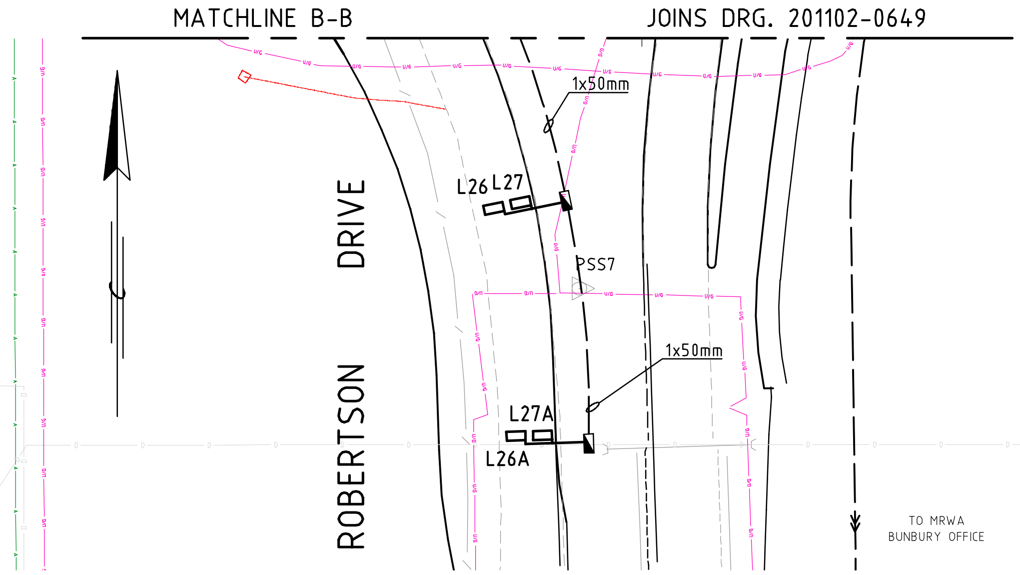
SURVEY CONTROL POINTS		
POINT No.	EASTING	NORTHING
PSS1	35945.072	109947.744
PSS2	35903.726	110014.545
PSS3	36083.270	110103.648
PSS4	36116.794	110030.443
PSS5	36205.754	109952.297
PSS6	36106.225	109851.625
PSS7	36091.853	109776.126

SERVICES

- EXISTING OVERHEAD POWER
- EXISTING TELSTRA DISTRIBUTION
- EXISTING WATER MAIN
- EXISTING SEWER PRESSURE MAIN
- EXISTING GAS MAIN
- EXISTING DRAINAGE
- EXISTING UNDERGROUND POWER
- EXISTING OPTUS
- EXISTING AQUAWEST

DIAL BEFORE YOU DIG
www.1100.com.au

WARNING
SERVICES AND CADASTRAL BOUNDARY LOCATIONS SHOWN ARE ONLY INDICATIVE AND MUST NOT BE USED FOR EXCAVATION. THE "ONE CALL 1100" SYSTEM SHALL BE USED TO OBTAIN ACCURATE SERVICE LOCATIONS.



* L26 & L27 = 75m FROM STOPLINE
* L26A & L27A = 100m FROM STOPLINE

TRAFFIC SIGNAL POST LOCATIONS		
POST No.	CO-ORDINATES	
	EASTING	NORTHING
1	36048.295	109873.939
2	36044.753	109858.848
3	36048.560	109854.880
4	36038.447	109843.425
5	36031.373	109838.476
6	36010.808	109859.698
7	36016.696	109865.477
8	36026.232	109882.560
9	35985.403	109983.691
10	35970.558	109988.149
11	35964.824	110002.174
12	35961.741	110009.715
13	35976.818	110022.634

TRAFFIC SIGNAL POST LOCATIONS		
POST No.	CO-ORDINATES	
	EASTING	NORTHING
14	35979.956	110014.958
15	35995.323	110003.988
16	36099.382	110039.750
17	36104.464	110054.411
18	36116.966	110064.568
19	36133.331	110045.668
20	36121.124	110028.532
21	36152.427	109930.042
22	36165.207	109925.574
23	36174.629	109913.434
24	36152.439	109893.244
25	36138.309	109904.584

AMENDMENTS

No.	DATE	DESCRIPTION	APPROVED
0	2.11.2011	SAME AS TENDER DRAWING REV F.	LP
1	07.02.2012	CONDUIT QUANTITES AMENDED	DN
2	06.03.2012	P8 AND CABINET LOCATION AMENDED	STT
3	13.03.2012	POLES 11,12 & 13 RELOCATED & 14-25 RENUMBERED	STT
4	02.04.2012	LOOP NUMBERS AMENDED	STT

NOTES

1. THIS DRAWING IS TO BE READ IN CONJUNCTION WITH THE MRWA SPECIFICATIONS.

NEW SITE - LM1071

CONTROLLER	RTA TSC/4
LANTERNS	LED
COMMUNICATIONS	SCATS - FIBRE OPTIC

REFERENCES

DESCRIPTION	DRAWING No.
LEGEND (TRAFFIC SIGNALS)	8320-0400
LEGEND (SYMBOLS)	8525-0316 & 8525-0317
CONDUITS (STANDARD)	8420-0700
RAISED PAVEMENT MARKERS	9120-0158 & 9120-0159
PEDESTRIAN RAMP DETAILS	9331-380
KERBING TYPE	9331-376
CHANNELISATION	MRWA
TRAFFIC SIGNAL POLE AND LOOP LAYOUT	201102-0649 TO 0651
MINOR SIGNING AND PAVEMENT MARKINGS	MRWA

METADATA

GROUND SURVEY STANDARD:	-
DATE OF CAPTURE:	2011
MAPPING SURVEY STANDARD:	67-08-43
DATE OF CAPTURE:	2011
MAIN ROADS PROJECT ZONE:	PCG-94
HEIGHT DATUM:	AHD

Government of Western Australia
mainroads WESTERN AUSTRALIA
SOUTH WEST REGION
ROBERTSON DRIVE BUNBURY 6230
Telephone (08) 9724 5600 Fax (08) 9724 5656

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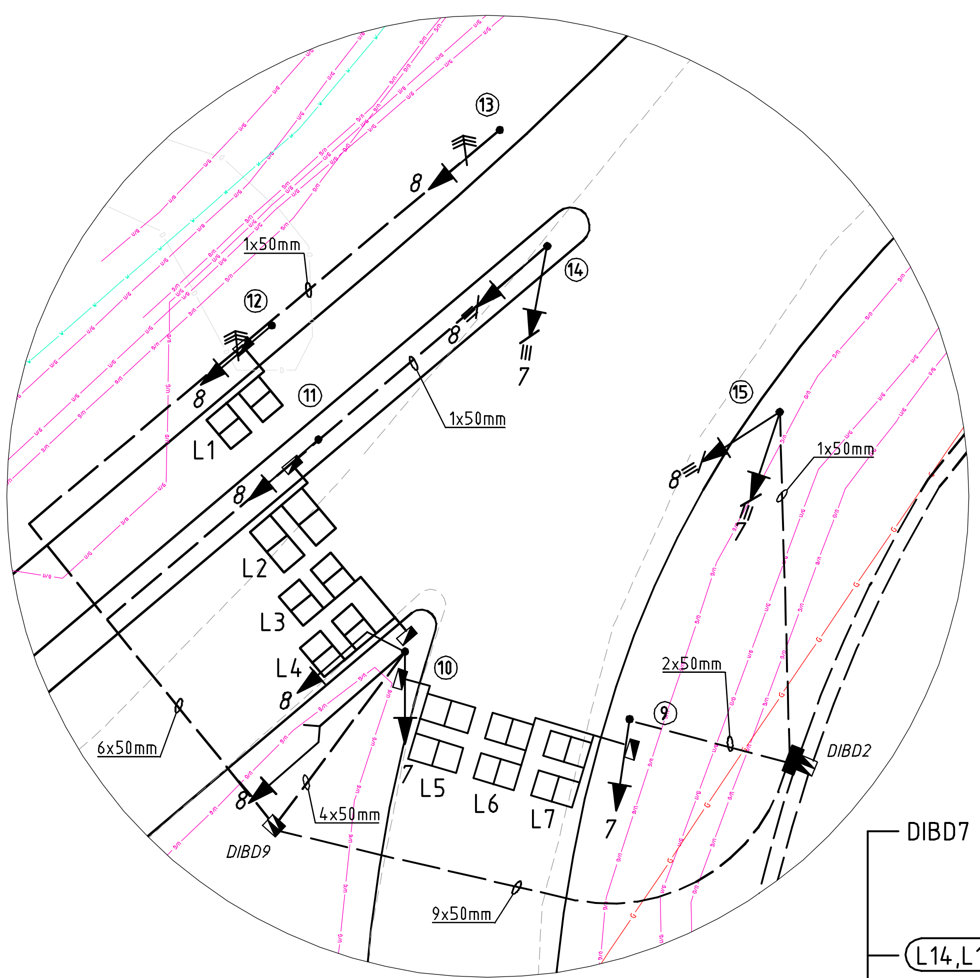
DRAWING NUMBER/DOCUMENT ID 61/26769

DESIGNED / DRAWN	P. VARDY	
VERIFIED	S. T. TAN	16.11.2011
DIRECTOR	S. T. TAN	16.11.2011
RECOMMENDED (MRWA)	L. PALANDRI	17.11.2011
APPROVED (MRWA)	B. BELSTEAD	18.11.2011

SCALES 1:20 1:500
A1

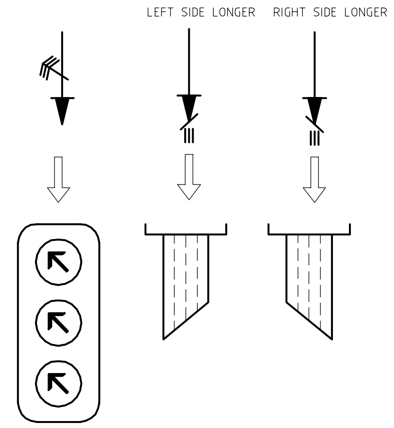
PERTH - BUNBURY HIGHWAY (H002)
EELUP ROUNDABOUT INTERIM UPGRADE
160.64 SLK TO 161.82 SLK
TRAFFIC SIGNALS
SHEET 2 OF 3

LOCAL AUTHORITY (204) CITY OF BUNBURY
MRWA DRAWING NUMBER
201102-0650-4

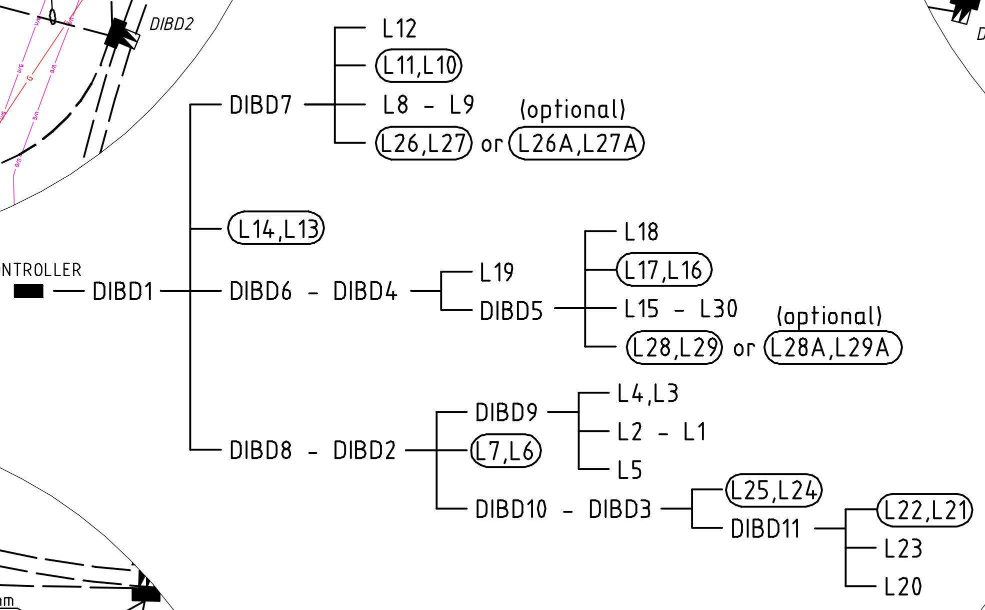


DETAIL 2 - 1:250

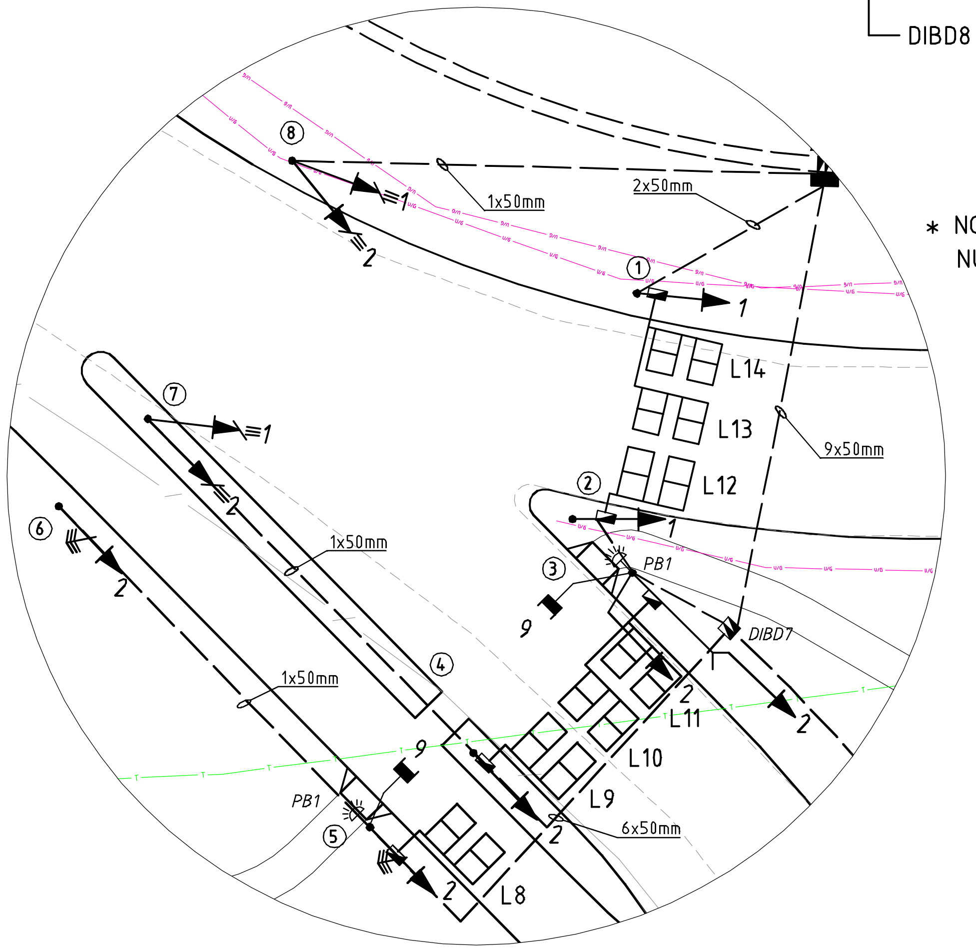
LEGEND LANTERNS



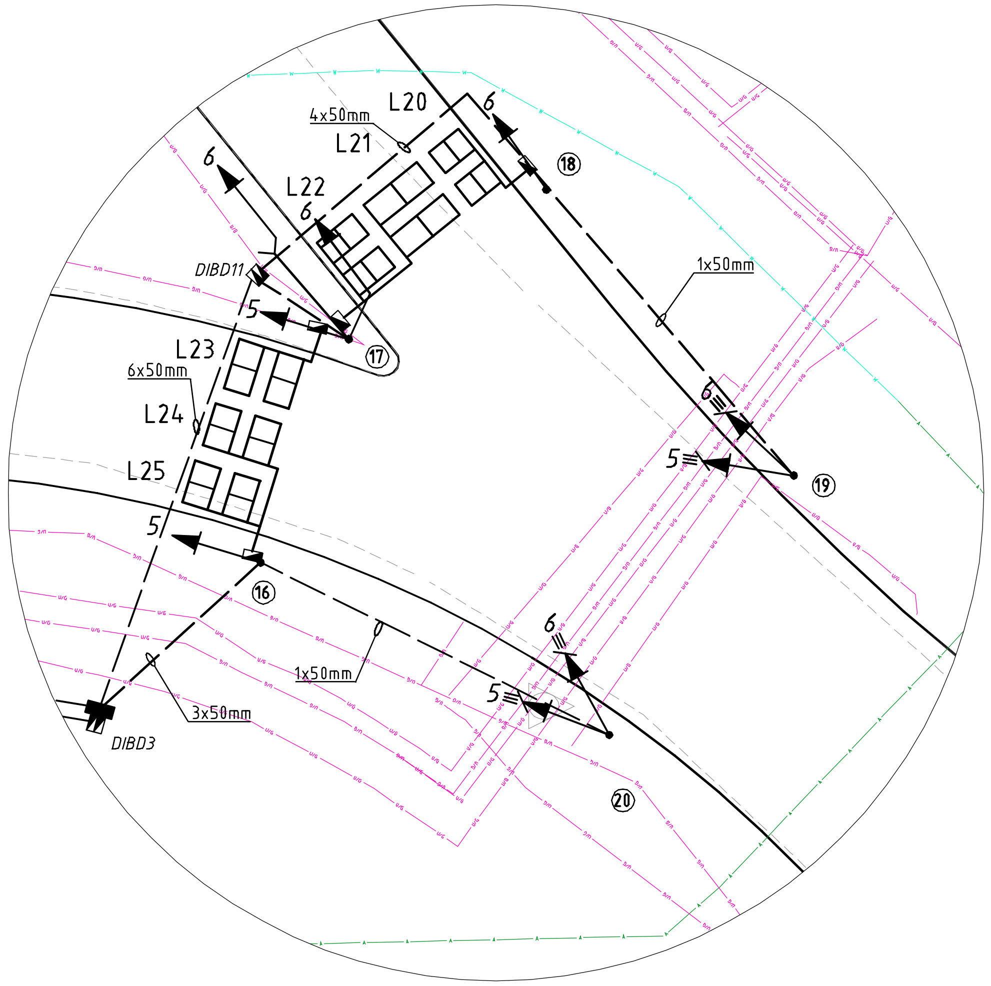
LOOP FEEDER CABLE ROUTE



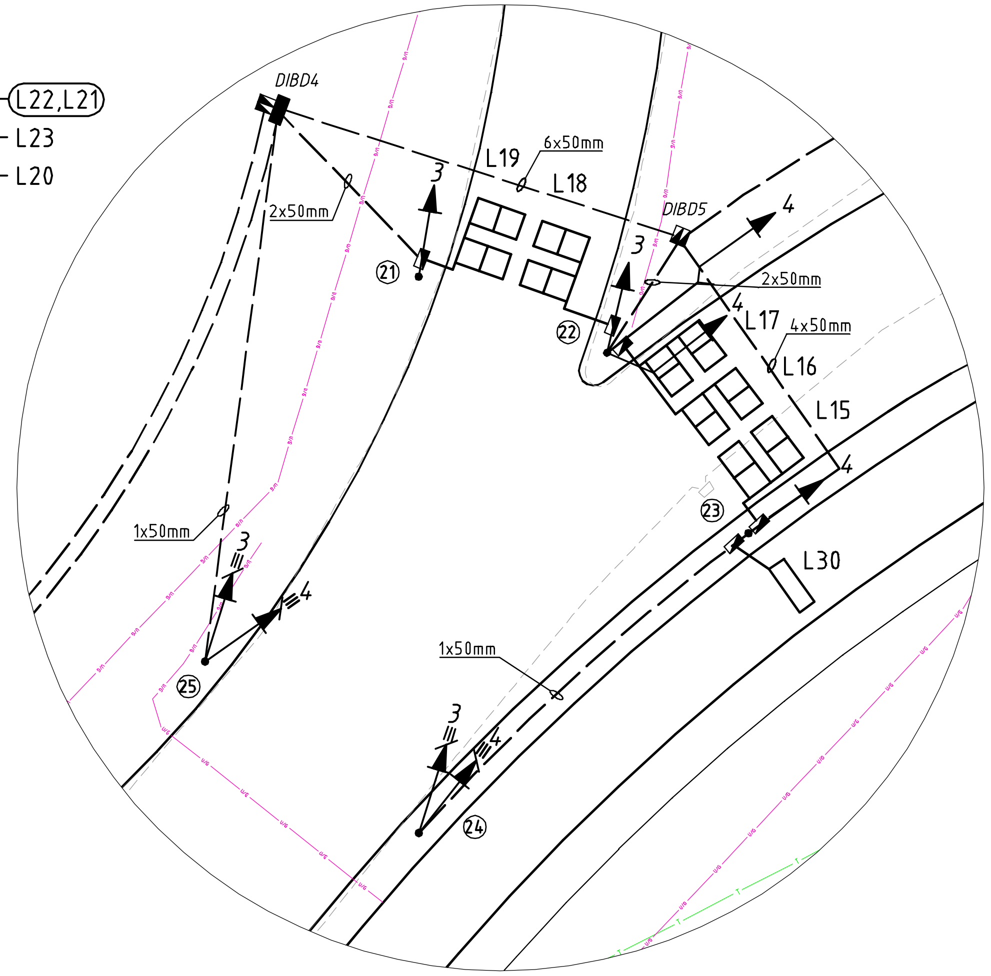
* NOTE: LOOPS CIRCLED ARE PARALLELED TO LIMIT NUMBER OF LOOPS IN CONTROLLER



DETAIL 1 - 1:250



DETAIL 3 - 1:250



DETAIL 4 - 1:250

AMENDMENTS

No.	DATE	DESCRIPTION	APPROVED
0	2.11.2011	SAME AS TENDER DRAWING REV E.	LP
1	24.01.2012	DETAIL 2 & 4 CONDUITS AMENDED	DN
2	13.03.2012	DETAIL 2 PED CROSSING DELETED	STT
3	02.04.2012	LFCR AND LOOP NO'S AMENDED	STT

NOTES

1. THIS DRAWING IS TO BE READ IN CONJUNCTION WITH THE MRWA SPECIFICATIONS.
2. INSTALL WALK/DONT WALK LANTERNS ON POSTS AS SHOWN
3. NEW AUDIO TACTILE PUSH BUTTONS TO BE POSITIONED TO THE SIDE OF THE POSTS SUCH THAT THE ARROW IS POINTING IN THE DIRECTION OF TRAVEL. AUDIO TACTILE DRIVER UNITS ARE TO BE INSTALLED.
4. ALL TRAFFIC LANTERNS ARE LED BASED, INCLUDING W/DW LANTERNS

NEW SITE - LM1071

CONTROLLER	RTA TSC/4
LANTERNS	LED
COMMUNICATIONS	SCATS - FIBRE OPTIC

REFERENCES

DESCRIPTION	DRAWING No.
LEGEND (TRAFFIC SIGNALS)	8320-0400
LEGEND (SYMBOLS)	8525-0316 & 8525-0317
CONDUITS (STANDARD)	8420-0700
RAISED PAVEMENT MARKERS	9120-0158 & 9120-0159
PEDESTRIAN RAMP DETAILS	9331-380
KERBING TYPE	9331-376
CHANNELISATION	MRWA
TRAFFIC SIGNAL POLE AND LOOP LAYOUT	201102-0649 TO 0651
MINOR SIGNING AND PAVEMENT MARKINGS	MRWA

METADATA

GROUND SURVEY STANDARD:	-
DATE OF CAPTURE:	2011
MAPPING SURVEY STANDARD:	67-08-43
DATE OF CAPTURE:	2011
MAIN ROADS PROJECT ZONE:	PCG-94
HEIGHT DATUM:	AHD

Government of Western Australia
mainroads WESTERN AUSTRALIA
SOUTH WEST REGION
ROBERTSON DRIVE BUNBURY 6230
Telephone (08) 9724 5600 Fax (08) 9724 5656

CONSULTANT
GHD
CLIENTS PEOPLE PERFORMANCE
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PO Box Y3106 Perth WA 6832 Australia
T (08) 6222 8222 F (08) 6222 8555
E permail@ghd.com.au www.ghd.com.au

DRAWING NUMBER/DOCUMENT ID 61/26769

DESIGNED / DRAWN	P. VARDY	
VERIFIED	S. T. TAN	16.11.2011
DIRECTOR	S. T. TAN	16.11.2011
RECOMMENDED (MRWA)	L. PALANDRI	17.11.2011
APPROVED (MRWA)	B. BELSTEAD	18.11.2011

SCALES 1:250
0 2.5m 5 7.5 10 12.5 15 17.5 20 22.5 25 27.5 30 32.5 35 37.5

A1

PERTH - BUNBURY HIGHWAY (H002)

EELUP ROUNDABOUT INTERIM UPGRADE - (STAGE 2)

160.64 SLK TO 161.82 SLK

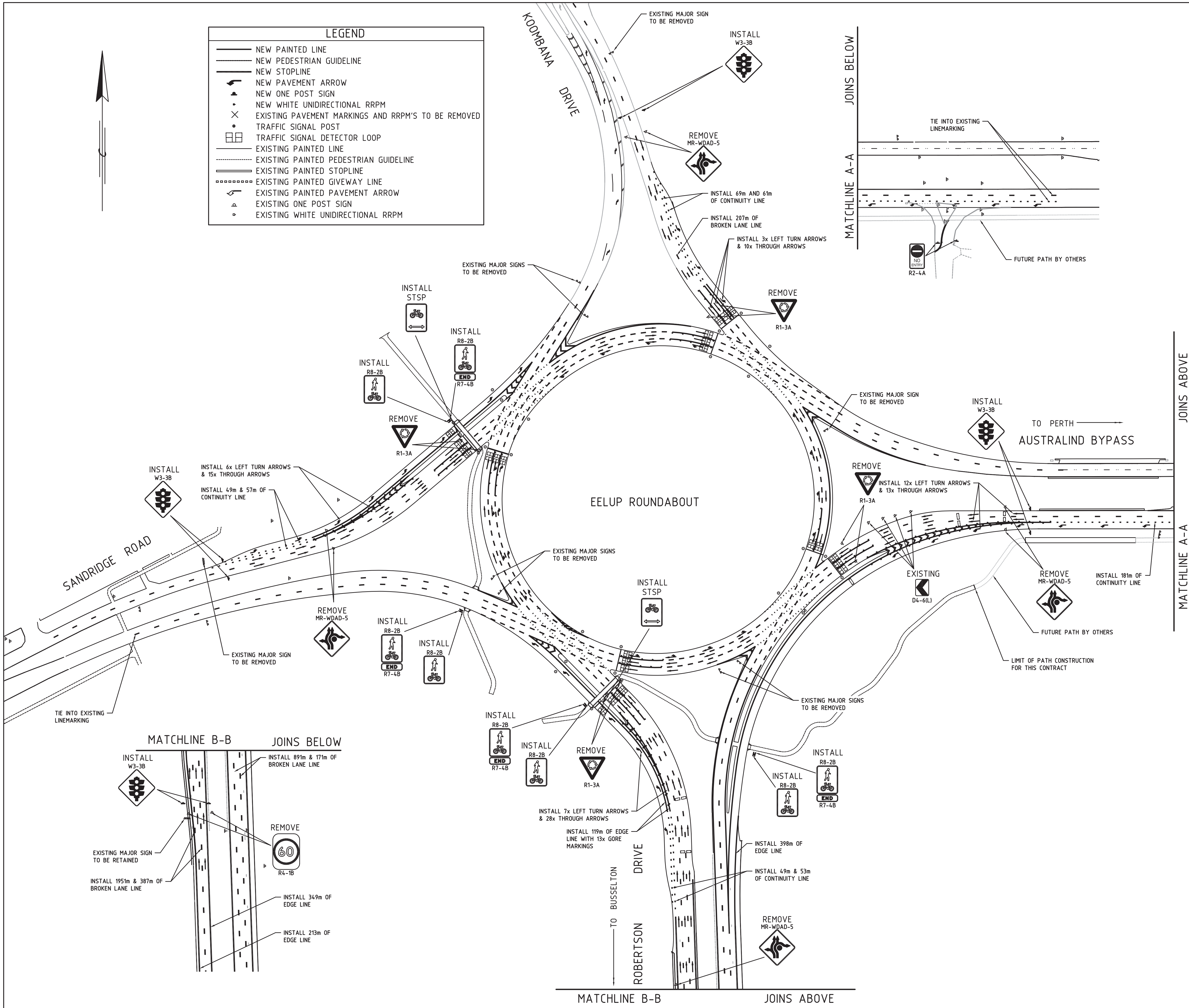
TRAFFIC SIGNALS

SHEET 3 OF 3

LOCAL AUTHORITY (204) CITY OF BUNBURY

MRWA DRAWING NUMBER

201102-0651-3



AMENDMENTS

No.	DESCRIPTION	APPROVED & DATE
0	SAME AS TENDER DRAWING REVISION C.	L.P. 2.11.2011

NOTES

1. THIS DRAWING IS TO BE READ IN CONJUNCTION WITH THE MRWA SPECIFICATIONS.
2. PAVEMENT MARKINGS TO BE ADDED/REMOVED AS SHOWN.
3. SIGNS TO BE ADDED/REMOVED/RELOCATED AS SHOWN.
4. USE ALL EXISTING MATERIALS ON SITE WHERE POSSIBLE.
5. ALL EXISTING PAVEMENT MARKINGS TO BE REMOVED BY WET GRINDING.
6. ALL NEW PAVEMENT MARKINGS AND ARROWS TO BE SET OUT WITH DESIGN STRINGS.
7. ALL EXISTING SIGNS DENOTED FOR REMOVAL SHALL BE CAREFULLY REMOVED AND STORED AT THE MAIN ROADS DEPOT IN BUNBURY.

NEW SITE - LM1071

REFERENCES

DESCRIPTION	DRAWING No.
LEGEND (TRAFFIC SIGNALS)	8320-0400
LEGEND (SYMBOLS)	8525-0316 & 8525-0317
CONDUITS (STANDARD)	8420-0700
RAISED PAVEMENT MARKERS	9120-0158 & 9120-0159
PEDESTRIAN RAMP DETAILS	9331-380
KERBING TYPE	9331-376
CHANNELISATION	MRWA
TRAFFIC SIGNAL POLE AND LOOP LAYOUT	61-26769-002 TO 004
MINOR SIGNING AND PAVEMENT MARKINGS	61-26769-005 & 006

METADATA

GROUND SURVEY STANDARD:	-
DATE OF CAPTURE:	2011
MAPPING SURVEY STANDARD:	67-08-43
DATE OF CAPTURE:	2011
MAIN ROADS PROJECT ZONE:	PCG-94
HEIGHT DATUM:	AHD

Government of Western Australia
mainroads WESTERN AUSTRALIA

SOUTH WEST REGION

ROBERTSON DRIVE BUNBURY 6231
Telephone (08) 9725 5600 Fax (08) 9724 5656

FILE NUMBER

DESIGNED / DRAWN	R. GAZENDAM	
VERIFIED	L. PALANDRI	23.11.2011
APPROVED	B. BELSTEAD	24.11.2011

SCALES 1:1000 A1

PERTH - BUNBURY HIGHWAY (H002)

EELUP ROUNDABOUT INTERIN UPGRADE

160.64 SLK TO 161.82 SLK

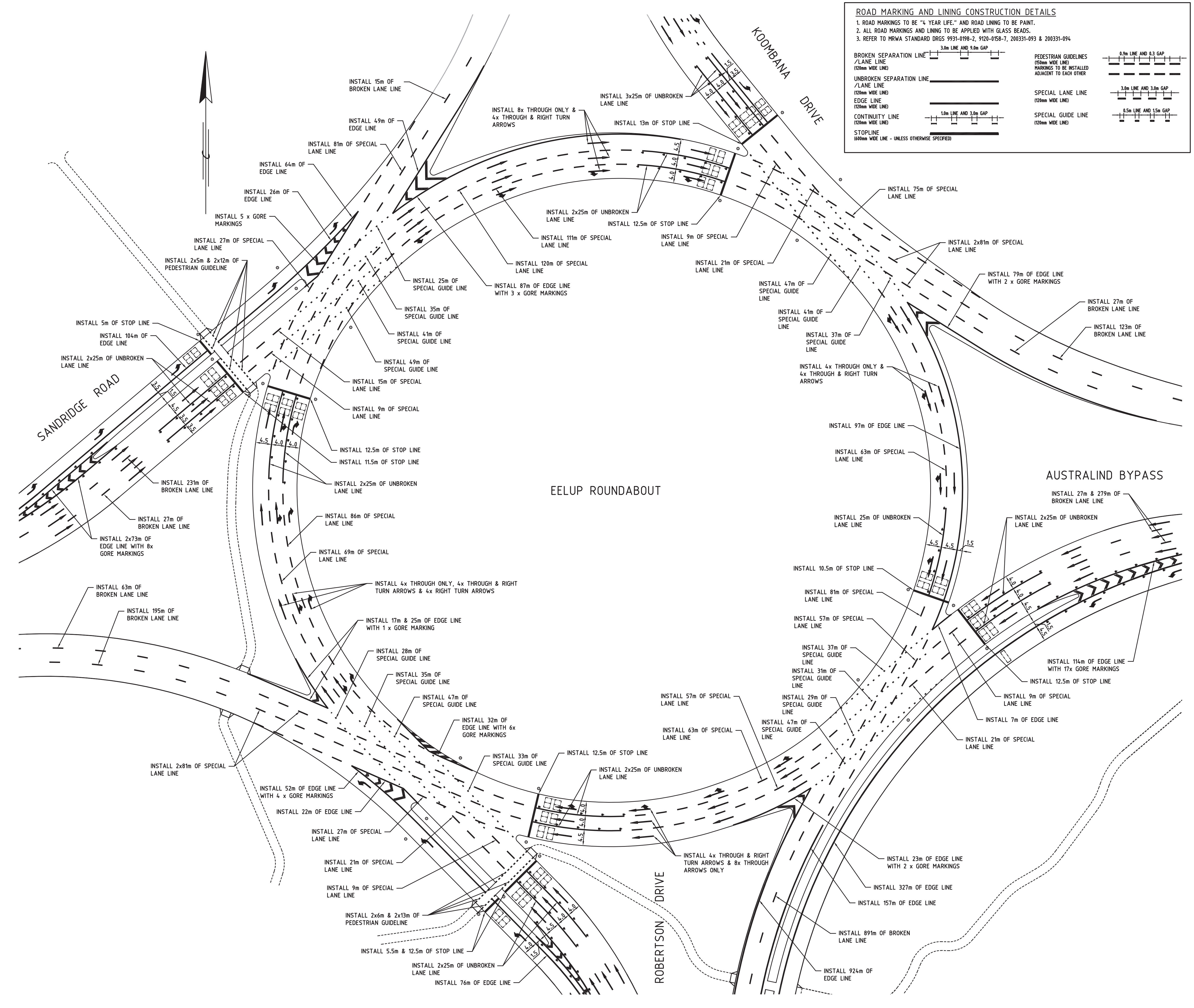
PAVEMENT MARKINGS & MINOR SIGNING

SHEET 1 OF 2

LOCAL AUTHORITY (204) CITY OF BUNBURY

MRWA DRAWING NUMBER

201102-0632



ROAD MARKING AND LINING CONSTRUCTION DETAILS

1. ROAD MARKINGS TO BE "4 YEAR LIFE." AND ROAD LINING TO BE PAINT.
2. ALL ROAD MARKINGS AND LINING TO BE APPLIED WITH GLASS BEADS.
3. REFER TO MRWA STANDARD DRGS 9931-0198-2, 9120-0158-7, 200331-093 & 200331-094

BROKEN SEPARATION LINE /LANE LINE (120mm WIDE LINE)	3.0m LINE AND 9.0m GAP
UNBROKEN SEPARATION LINE /LANE LINE (120mm WIDE LINE)	
EDGE LINE (120mm WIDE LINE)	
CONTINUITY LINE (120mm WIDE LINE)	1.0m LINE AND 3.0m GAP
STOPLINE (600mm WIDE LINE - UNLESS OTHERWISE SPECIFIED)	
PEDESTRIAN GUIDELINES (150mm WIDE LINE) MARKINGS TO BE INSTALLED ADJACENT TO EACH OTHER	0.9m LINE AND 0.3 GAP
SPECIAL LANE LINE (120mm WIDE LINE)	3.0m LINE AND 3.0m GAP
SPECIAL GUIDE LINE (120mm WIDE LINE)	0.5m LINE AND 1.5m GAP

AMENDMENTS

No.	DESCRIPTION	APPROVED & DATE
0	SAME AS TENDER DRAWING REVISION C.	L.P. 2.11.2011

NOTES

1. THIS DRAWING IS TO BE READ IN CONJUNCTION WITH THE MRWA SPECIFICATIONS.
2. PAVEMENT MARKINGS TO BE ADDED/REMOVED AS SHOWN.
3. SIGNS TO BE ADDED/REMOVED/RELOCATED AS SHOWN.
4. USE ALL EXISTING MATERIALS ON SITE WHERE POSSIBLE.
5. ALL EXISTING PAVEMENT MARKINGS TO BE REMOVED BY WET GRINDING.

NEW SITE - LM1071

REFERENCES

DESCRIPTION	DRAWING No.
LEGEND (TRAFFIC SIGNALS)	8320-0400
LEGEND (SYMBOLS)	8525-0316 & 8525-0317
CONDUITS (STANDARD)	8420-0700
RAISED PAVEMENT MARKERS	9120-0158 & 9120-0159
PEDESTRIAN RAMP DETAILS	9331-380
KERBING TYPE	9331-376
CHANNELISATION	MRWA
TRAFFIC SIGNAL POLE AND LOOP LAYOUT	61-26769-002 TO 004
MINOR SIGNING AND PAVEMENT MARKINGS	61-26769-005 & 006

METADATA

GROUND SURVEY STANDARD:	-
DATE OF CAPTURE:	2011
MAPPING SURVEY STANDARD:	67-08-43
DATE OF CAPTURE:	2011
MAIN ROADS PROJECT ZONE:	PCG-94
HEIGHT DATUM:	AHD

Government of Western Australia

mainroads WESTERN AUSTRALIA

SOUTH WEST REGION

ROBERTSON DRIVE BUNBURY 6231
Telephone (08) 9725 5600 Fax (08) 9724 5656

FILE NUMBER

DESIGNED / DRAWN	R. GAZENDAM	
VERIFIED	L. PALANDRI	23.11.2011
APPROVED	B. BELSTEAD	24.11.2011

1:500

SCALES

A1

PERTH - BUNBURY HIGHWAY (H002)
EELUP ROUNDABOUT INTERIM UPGRADE
160.64 SLK TO 161.82 SLK
PAVEMENT MARKINGS & MINOR SIGNING
SHEET 2 OF 2

LOCAL AUTHORITY (204) CITY OF BUNBURY

MRWA DRAWING NUMBER
201102-0633